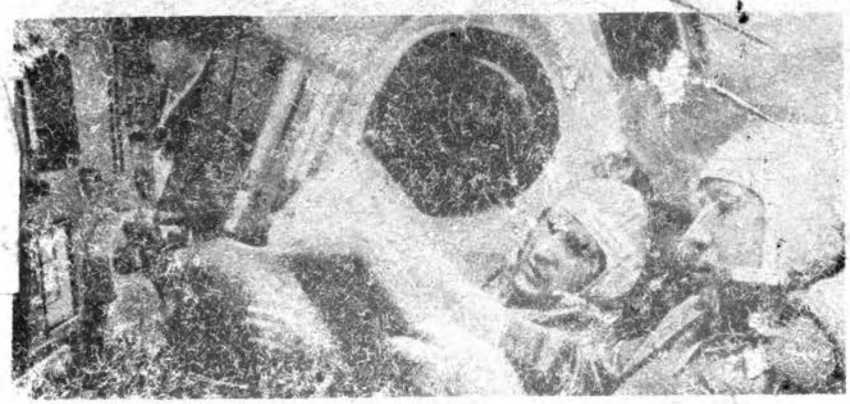
SPACEFLIG

Volume 17 No. 1 January 1975



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SPACEFLIGHT

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COVER

A MEETING IN SPACE. In a major breakthrough in space cooperation the Apollo-Soyuz Test Project is scheduled to begin on 15 July with real-time TV coverage of the launch of a two-man Soyuz spacecraft from Tyuratam in Central Asia. The craft will take up a rendezvous orbit at 143 miles (230 km) inclined at 51.8 deg to the equator. At the Kennedy Space Center in Florida 7½ hours after the Soyuz lift-off, a Saturn IB will rocket the three-man Apollo CSM into a 93-106 miles (150-170 km) orbit that will be circularised at 143 miles as Apollo closes with Soyuz. Docking should occur some 50 hours after the launch of Apollo, and the duration of docked operations will be about 48 hours. *Top left*, the Apollo crew Donald K. Slayton, Vance D. Brand and Thomas P. Stafford. *Right and below*, Soyuz flight crew Alexei Leonov and Valeriy Kubasov in training. For story see page 2.

National Aeronautics and Space Administration and Novosti Press Agency.

MILESTONES

October

7 Salyut 3 completes 1,676 revolutions of the Earth by 11 a.m. (Moscow time). Orbital parameters are 249-293 km, inclination to equator 51.6 deg; period 89.7 min.

15 Britain's 288 lb. (131 kg) UK-5 (Ariel 5) X-ray satellite launched by NASA Scout rocket by Italian team from San Marco platform offshore of Kenya (see *Spaceflight* October 1974 pp. 387-388).

16 French Government – after Cabinet Meeting under President Giscard d'Estaing – reaffirms decision to build L.3S Ariane launch vehicle within ESRO/ESA programme.

16 Soviets announce that between 20-30 October carrier rockets will be launched into an area of the Pacific with a radius of 130 n. miles centred at 34°49'N, 177°14'W.

20 Soviets launch ICBM on test between Tyuratam cosmodrome and Pacific target area, a distance of some 5,700 miles.

22 Soviets launch Cosmos 690 from Plesetsk containing "perfected experimental systems with laboratory animals and other biological subjects and scientific equipment for assessing their condition". Orbit is 223-389 km inclined at 62.8 deg to equator.

23 Soviets launch second ICBM from Tyuratam into Pacific target area which is then re-opened to shipping and aircraft.

24 Soviet Mission Control manoeuvres Salyut 3 into orbit of 268-299 km at 51.6 deg inclination.

24 USAF launches Minuteman 1 ICBM with live first stage (igniting for 10 sec.) from C-5A Galaxy transport over Western Test Range, California.

27 Salyut 3 completes 2,000 revolutions of the Earth at 2.30 p.m. (Moscow time), having operated in "controllable flight conditions with continuous automatic stabilisation. It has completed over 100 manoeuvres, including eight orbit corrections by Earth command". Additional research programme includes: study of aerodynamic/ballistic characteristics, influence of gravitational forces and moments in the change of position of panels of solar batteries, parameters of heat exchanges, thermal control, electrical supply and control system characteristics.

28 Soviets launch Luna 23 from Tyuratam by Proton rocket at 5.30 p.m. (Moscow time) to continue "scientific exploration of the Moon and near-lunar space".

November

2 Luna 23 is braked into orbit around the Moon at 94-104 km altitude inclined at 138 deg to equator; period 1 hr 57 min.

4-5 Luna 23 is manoeuvred into orbit of 17-105 km in readiness for soft-landing attempt.

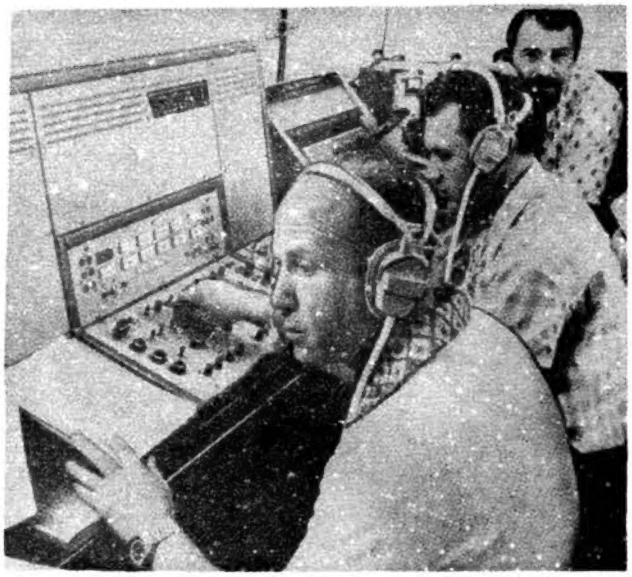
6 Lunar 23 lands at 8.37 a.m. (Moscow time) in rugged area of the southern part of the Sea of Crises but damage to rock drill device frustrates sampling attempt. [Restricted programme of research conducted until 9 November.]

A MEETING IN SPACE

A review of the forthcoming Apollo Soyuz Test Project by the Staff of NASA

On 15 July 1975 a group of B.I.S. Members* will witness the launch from the Kennedy Space Center, Florida, of the Apollo spacecraft involved in the ASTP joint docking experiment with the Soviet Union. Aboard will be astronauts Thomas P. Stafford (commander), Donald K. ('Deke') Slayton and Vance D. Brand. The Soviet Soyuz spacecraft flown by Alexei A. Leonov and Valeriy N. Kubasov, launched 7½ hours earlier, will already have taken up station some 140 miles above the Earth in readiness for approach and docking manoeuvres by the American craft. This article gives the background to this historic meeting in space between the space teams of East and West which grew out of informal talks between Dr. Thomas O. Paine, the former NASA Administrator, and Soviet Academician Anatoly Blagonravov in New York in April 1970 (see *Spaceflight* November 1972 p. 405). The project was finally endorsed by former President Nixon and Chairman Kosygin at a Moscow "summit" on 24 May 1972 in the spirit of the détente. In the smooth and friendly relationships which have developed between the space teams could be a valuable lesson for future collaboration – in space and other fields of human endeavour.

Kenneth W. Gatland



The ASTP project directors have announced plans to conduct joint pre-launch tests at the Kennedy Space Center from 1-8 February 1975 and at the Tyuratam cosmodrome from 5-13 May 1975. These tests will include participation by the flight crews and technical specialists from both countries. Photo shows the prime Soyuz crew Lt-Col. Alexei A. Leonov, commander, and Valeriy N. Kubasov, civilian flight engineer during a flight simulation and compatability test at the Johnson Space Center, Houston, Texas.

National Aeronautics and Space Administration

Introduction

The Apollo Soyuz Test Project (ASTP) is a joint endeavour of the United States and the Soviet Union as part of the agreement on cooperation in space which President Nixon and Chairman Kosygin signed in Moscow in May of 1972. Both countries have agreed to develop compatible rendezvous and docking systems which will provide a basis for docking and rescue on future spacecraft of both nations, and to conduct a joint experimental mission in mid-1975 to rendezvous and dock a manned Apollo spacecraft with a manned Soyuz-type spacecraft to test these docking systems in orbit. Each nation is separately developing docking systems based on a mutually agreeable single set of interface design specifications.

The major new U.S. programme elements are the Docking Module and docking system necessary to achieve compatibility of rendezvous and docking systems with the USSR-developed hardware to be used on a Soyuz spacecraft. The Docking Module and system together with an Apollo Command and Service Module (CSM) will be launched on a Saturn IB launch vehicle. The Docking Module and the docking system will be stowed in the spacecraft launch vehicle adapter and extracted by the CSM while in Earth orbit in a manner similar to that used with the Lunar Module on an Apollo lunar mission.

The ASTP mission will include testing a compatible rendezvous system in orbit; testing the compatible docking systems; verifying techniques for transfer of astronauts and cosmonauts; conducting experiments while docked and undocked; developing experience for the conduct of potential joint flights by U.S. and USSR spacecraft, including, in case of necessity, rendering aid in emergency situations.

Joint US/USSR working groups have been meeting on a scheduled basis to review and agree on the technical and operational aspects of the joint project.

Apollo Command and Service Module

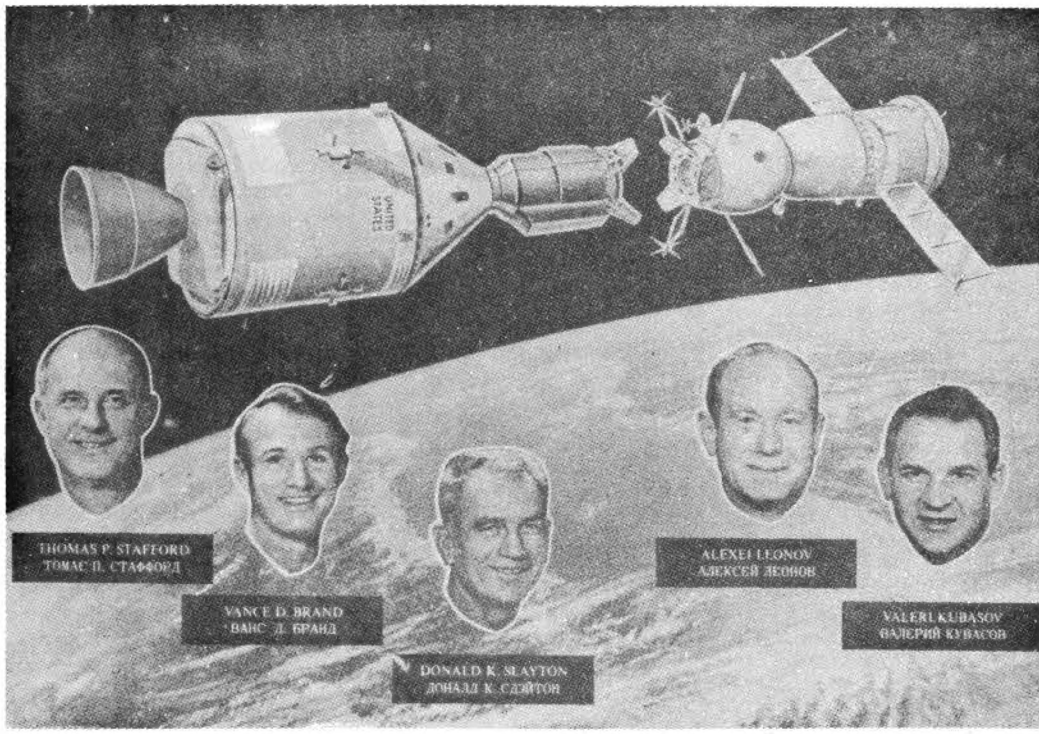
The Apollo spacecraft will be a modified version of the Command and Service Module (CSM) flown during the first several lunar landing missions. Major CSM modifications include provisions for experiments, additional propellent tanks for the reaction control system and the addition of controls and displays required for the proper operation of the Docking Module and docking system.

Docking Module and Docking System

The Docking Module is cylindrical, approximately 1.5 metres (about 5 ft.) in diameter and 3 metres (about 10 ft.) in length. It will serve as an airlock for the internal transfer of crewmen between the different atmospheres of the Apollo and Soyuz spacecraft. The Docking Module will be equipped with radio and TV communications, antennae, stored gases, heaters, and the displays and controls necessary for transfer operations.

The Docking Module is designed to handle two crewmen simultaneously. Hatches having controls on both sides will be installed at each end of the module. A universal docking system will be located at the Soyuz end of the module and will be capable of functioning with similar components on the Soyuz-type spacecraft. The Apollo end of the Docking

* *Members wishing to join this group, and who have not yet done so, are advised to contact Mr. L. J. Carter, Executive Secretary, British Interplanetary Society, London, SW1V 2JJ, as soon as possible.*

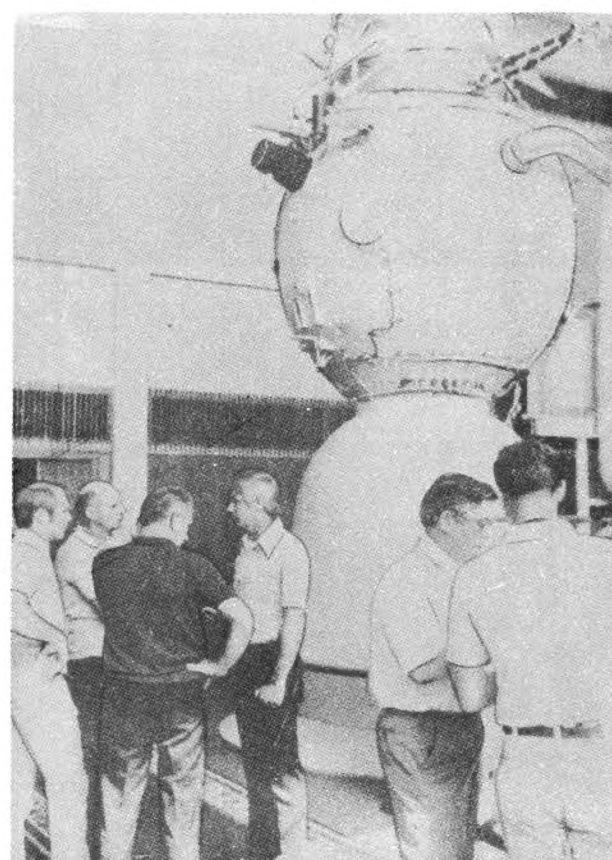


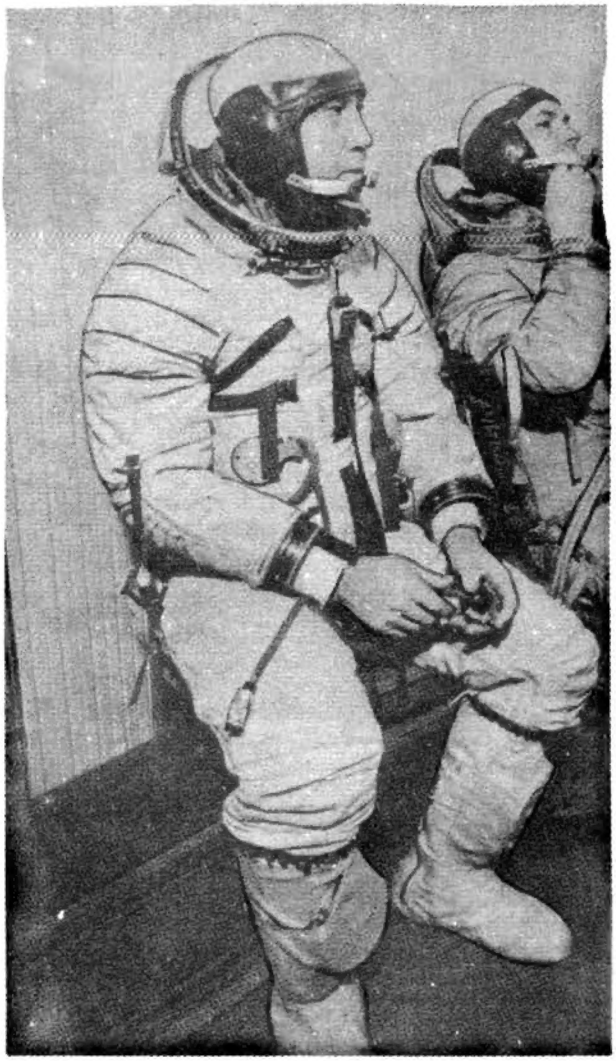
Men of the Apollo-Soyuz Test Project. Left to right, Brig-Gen. Thomas P. Stafford; Vance D. Brand; Donald K. ('Deke') Slayton; Lt-Col. Alexei Leonov, and Valeriy Kubasov. *Above,* artist's impression of Apollo and Soyuz in the docking posture.

National Aeronautics and Space Administration

Right, a group of American and Soviet ASTP personnel discuss procedures at the Cosmonaut Training Center (Star City) near Moscow. The Americans from the ASTP office at the Johnson Space Center were in the U.S.S.R. to participate in familiarisation training on the Soyuz systems. Group at far left: Vance D. Brand, Thomas P. Stafford, Donald K. Slayton and Eugene A. Cernan, special assistant to the U.S. Technical Director of ASTP.

Below, Astronauts Ronald E. Evans and Alan L. Bean, U.S. Flight Crew Support Members during a Russian language session with instructor James Flannery at the Johnson Space Center.





ASTP IS SYMBOLIC OF A NEW HUMAN RELATIONSHIP

A large portion of the remarks former President Nixon made by radio and television to the people of the Soviet Union during his 1974 visit to Moscow concerned the Apollo-Soyuz Test Project and the effect it can have toward bringing about a lasting peace between the two nations.

His statement follows in part:

"As allies in World War II, we fought side by side in the most terrible war in all human history. And together with our allies we won the victory. In winning that victory, the people of the Soviet Union and the people of the United States shared a common hope that we also had won a lasting peace. That hope was frustrated, but now we have a new opportunity.

"Winning victory in war is difficult. It requires extraordinary courage, stamina, and dedication from every individual citizen in the nation. But in some ways, the building of a lasting peace is even more difficult than waging war because it is more complex. We must bring to the task of building that peace the same kind of courage, of stamina, of dedication that inspired us in our struggle for victory in war.

"And the fact that our task of building peace is more complex does not mean that we cannot succeed.

"Let me give a striking example which demonstrates that point. In the whole field of modern technology, no mission is more complex than the mission of sending men into space. The joint Soviet-American mission planned for next year – the joint Soyuz-Apollo mission – is in many ways symbolic of the new relationship we are building between our two nations."

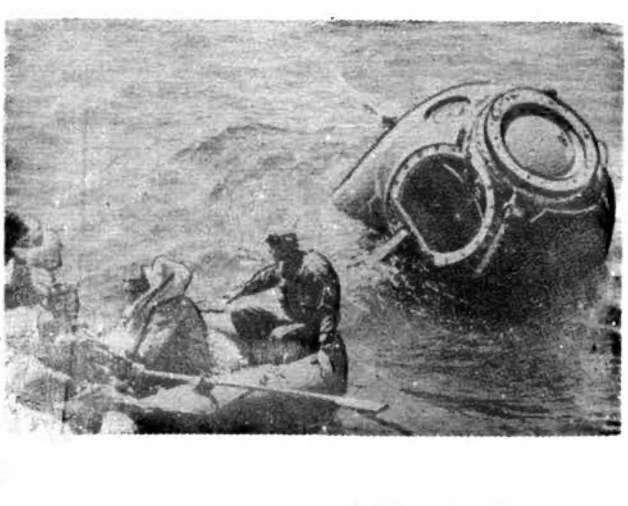
"It is symbolic for several reasons – reasons which carry important lessons about that new relationship.

"For one thing, the rocket technology developed for war is being used for peace.

"And for another, Soviet and American spacemen, starting from their separate countries, will find their way toward one another and join with one another – just as we are doing and must continue to do across the whole range of our relationship.

"By standardizing their docking techniques, they will make international rescue missions possible in case future space missions encounter trouble in space; thus they will make space safer for the astronauts and cosmonauts of both our countries – just as our new relationship can make life on Earth safer for the people of both of our countries.

"Finally, and perhaps more important, this joint mission – for which our astronauts are now here in the Soviet Union training alongside your cosmonauts – is being made possible by careful planning, by precise engineering, by a process of working and building together, step by step, to reach a goal that we share, and this is the way that together we can build a peace, a peace that will last."



Top left, Leonov and Kubasov during training for emergency water recovery of the Soyuz command module. Under normal conditions the ASTP Soyuz will make a soft-landing in Kazakhstan.

Left, practising water recovery in the Black Sea in an operation reminiscent of an Apollo splashdown.

Novosti Press Agency

Module will use the probe and drogue docking system used during the Apollo lunar programme to permit docking between the Command Module and Lunar Module.

In orbit, Apollo's atmosphere is pure oxygen at a pressure of five pounds per square inch. Soyuz uses a mixture of nitrogen and oxygen at an Earth sea level pressure of 14.7 pounds per square inch. (Later NASA spacecraft such as the Space Shuttle will use nitrogen-oxygen at sea level pressure).

While the spacecraft are docked, the Soyuz pressure will be reduced from its normal 14.7 pounds per square inch to 10 pounds. This will make it possible for crewmen to transfer from Soyuz to Apollo without taking time in the airlock to breathe pure oxygen and force nitrogen from their blood. Apollo pressure will remain at five pounds.

The Docking Module design emphasized low cost construction made possible by the launch weight margin inherent in the use of the Saturn IB launch vehicle. Thick aluminium plate was used rather than honeycomb, resulting in a considerable reduction in structural cost.

The Soviet Soyuz will also be modified. One important modification will be the use of a compatible rendezvous and docking system which NASA and Soviet engineers have designed. This system will also be employed on the end of the Docking Module with which Soyuz will dock.

Soyuz has been the primary Soviet manned spacecraft since its introduction in 1967. It consists of three basic modules:

1. *Orbital module,* located at the forward end, used by the crew for work and rest during orbit. It is 3.35 metres (7.3 ft.) in diameter, 2.65 metres (8.7 ft.) long, and weighs about 1,224 kg (2,700 lb.).

2. *Descent module,* with main controls and crew couches, used by crew during launch, descent, and landing. It weighs about 2,802 kg (6,200 lb.) and is 2.2 metres (7.2 ft.) long.

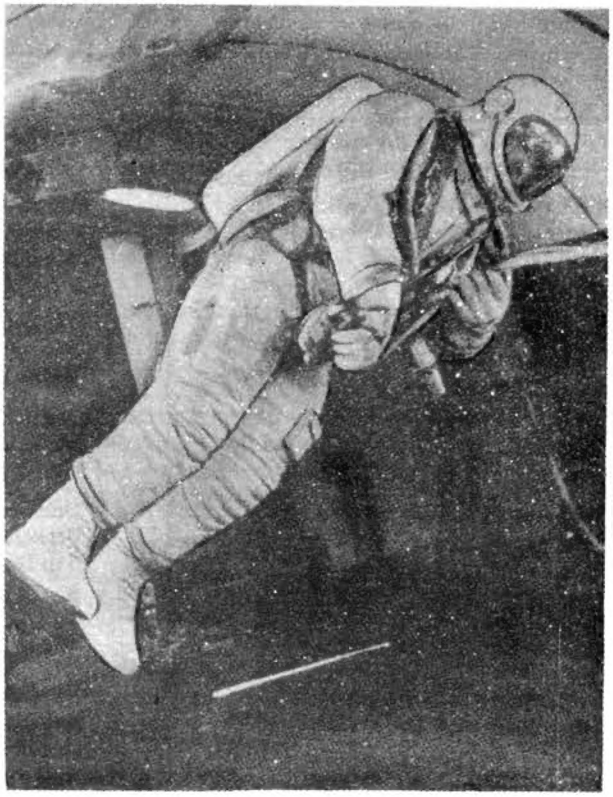
3. *Instrument module,* at rear, with subsystems required for power, communications, propulsion, and other functions. It weighs 2,654 kg (5,850 lb.) and is 2.3 metres (7.5 ft.) long.

Experiments

During the ASTP mission, the crew will conduct important new science, applications, technology and medical experiments.

The science experiments selected for the mission include astronomical observations in a region of the electromagnetic spectrum which has not been systematically surveyed by satellite instruments. The astronomical regions should significantly advance understanding of some of the spectacular new classes of objects discovered in the last few years (such as quasars, pulsars, and X-ray sources), and also provide important information on the nature of the interstellar medium. In addition, atmospheric observations will be conducted using a new technique for measuring atmospheric constituents which are too chemically reactive to measure directly with a mass spectrometer. This is a joint experiment with the USSR and will be accomplished by sending an optical signal from the CSM to a reflector on the Soyuz.

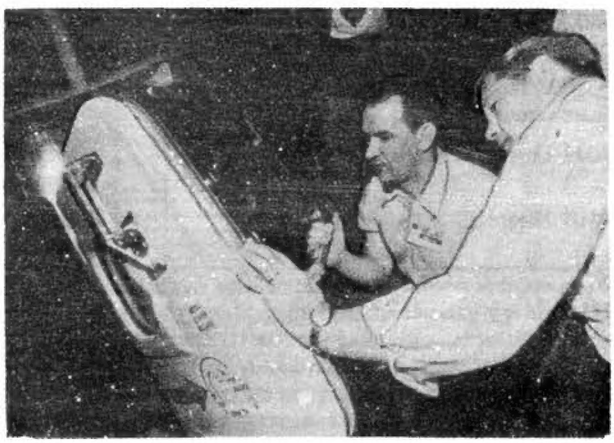
The signal will be bounced back and scanned in the Apollo spacecraft to study the effects of the Sun on atomic oxygen and nitrogen at orbital altitudes. These observations



Above, Alexei Leonov gets re-aquainted with zero-g during a space simulation carried out in a modified Soviet transport aircraft.

Below, Valeriy Kubasov operates the hatch release of the Apollo command module under the supervision of a test engineer at the Johnson Space Center.

Novosti Press Agency and NASA



ASTP Research Programme

Experiment	Contractor	Principal Investigator
MA-059 Ultra Violet Absorption – Principal Investigator Portion	University of Pittsburgh. Pittsburgh, Pennsylvania.	Dr. T. M. Donahue
MA-059 Ultra Violet Absorption – Spectrometer, Hardware Portion.	Naval Ordnance Systems/Applied Physics Laboratory, Johns Hopkins University. Silver Spring, Maryland.	
MA-059 Ultra Violet Absorption – Retroreflector, Array Portion.	Precision Lapping & Optical Company. Valley Stream, New York.	
M-136 Earth Observation and Photography.	Smithsonian Institution Air and Space Museum Washington, D.C.	
MA-083 Extreme Ultra Violet Telescope	University of California. Berkeley, California. Ball Brothers.	Dr. C. S. Bowyer
MA-088 Helium Glow.	University of California. Berkeley, California. Ball Brothers.	Dr. C. S. Bowyer
MA-089 Doppler Tracking (Design Phase).	Smithsonian Institution Astrophysical Observatory. Cambridge, Massachusetts.	Dr. G. C. Weiffenbach Dr. M. D. Grossi
MA-048 Soft X-ray.	Naval Research Laboratory. Washington, D.C.	Dr. H. Friedman
MA-106 Light Flash, Phase I.	AEC/Lawrence Radiation Laboratory University of California. Livermore, California.	Dr. C. A. Tobias Dr. T. F. Budinger
MA-017 Barium Cloud (Design Phase).	University of Alaska Geophysical Institute. Fairbanks, Alaska.	Dr. E. M. Wescott
MA-028 Crystal Growth	Science Center Rockwell International Thousand Oaks, California.	Dr. M. D. Lind
MA-031 Cellular Response	Baylor College of Medicine Houston, Texas.	Dr. B. Sue Criswell
MA-032 Polymorphonuclear Leukocyte Response.	Baylor College of Medicine Houston, Texas.	Dr. R. Russell Martin
AR-002 Microbial Exchange.	Johnson Space Center. Houston, Texas.	Dr. Gerald R. Taylor
MA-007 Stratospheric Aerosol Measurement.	University of Wyoming. Laramie, Wyoming.	Dr. T. J. Pepin
MA-011 Electrophoresis Technology	Max Planck Institute. Munich, Germany.	Professor Kurt Hannig
MA-107 Biostack.	University of Frankfurt. Frankfurt-on-Main, Germany.	Professor Horst Bucher

are important for a better understanding of the chemistry and the energy balance of the upper atmosphere. Data from these experiments could lead to a better understanding of the evolution of stars, of the emission processes which could lead to new methods of energy generation, and of the interaction of the upper and lower atmosphere where weather is generated.

The experiments in the field of applications and technology will investigate the space processing of new material samples in zero gravity utilizing an improved multipurpose furnace, and make Earth observations to determine detailed gravity features and geological structures which could indicate the presence of oil and mineral deposits. Also included is an experiment in electrophoresis processing. An electric

field is used to separate living cells and other biological materials from a flowing medium without decreasing their activity. It is expected to determine whether the near zero gravity conditions enhance a similar process now involved in work by the Max Planck Institute in Germany.

Successful demonstration by ASTP could lead to further development of space electrophoresis in Shuttle missions as a tool for medical research and therapy and contribute to such fields as immunology and cancer research.

The life sciences experiments include extension of work done in the Apollo and Skylab programmes, such as additional study of the phenomena of the cosmic light flashes observed by flight crews and studies of the effects of zero gravity and radiation on organisms. Studies will also be conducted on pre and post flight astronaut blood samples to determine, among other things, immunity retention. There are also joint US/USSR life science experiments planned, such as an experiment designed to determine the degree of transfer of micro-organism and microflora between crew members and the two spacecraft involved in this mission. This experiment is designed to take advantage of a mission involving two spacecraft launched from widely separated ground environments.

Launch Vehicle

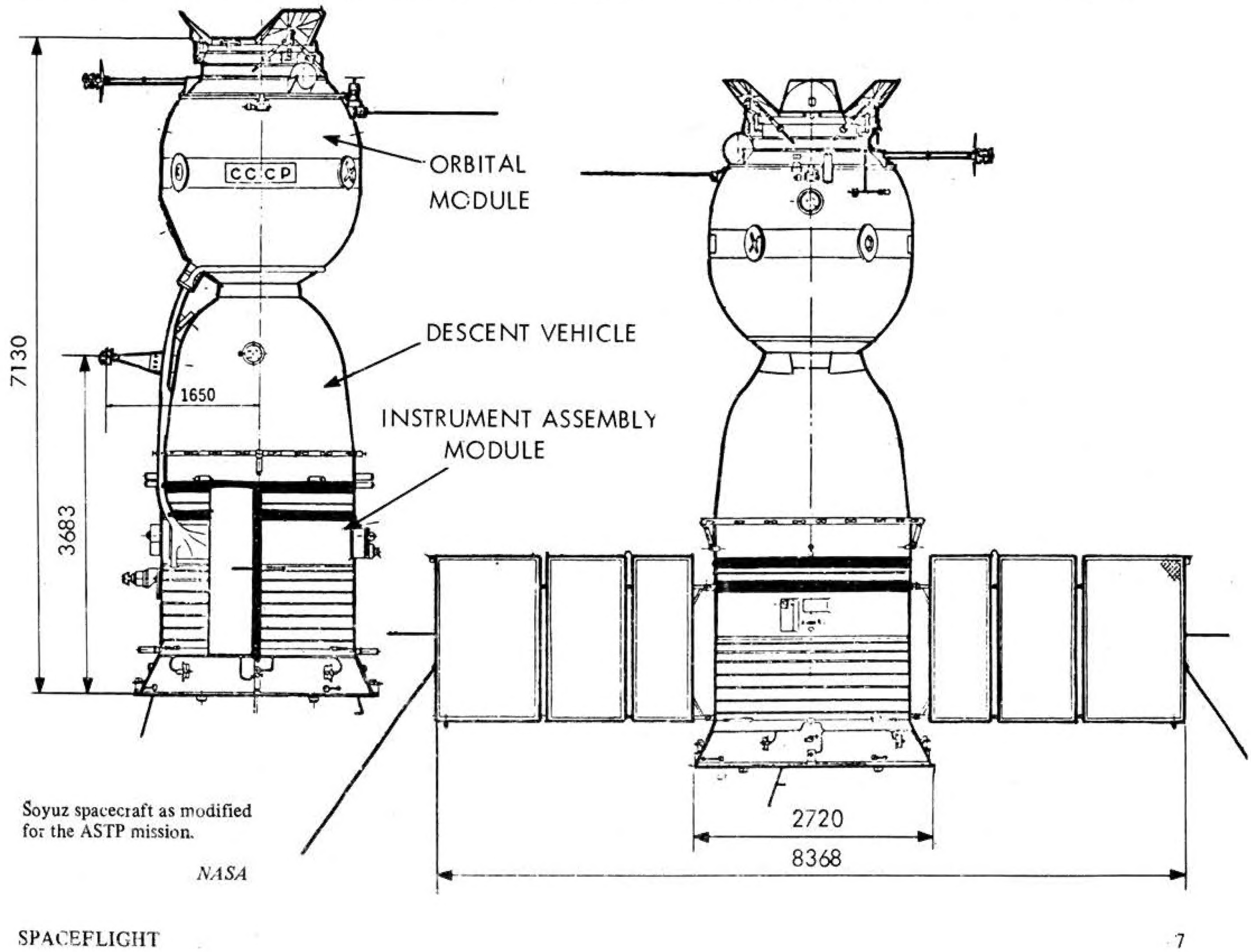
ASTP will utilize Apollo-Skylab Saturn IB launch vehicle hardware. The Saturn IB, consisting of an S-IB stage, an S-IVB stage, and an instrument unit, will launch the spacecraft from the Kennedy Space Center.

Planned Mission Summary

The Soyuz will be launched from the Tyuratam, Kazakhstan, launch complex at about 1220 GMT* on 15 July 1975, in a northeasterly direction and is inserted into a 188-by 228-km (117-by 142 mile) orbit at an inclination of 51.8°. On the fourth orbit after lift-off the Soyuz will initiate the first of two manoeuvres to circularize the orbit at 225 km (140 miles). The second manoeuvre for circularization will occur on the 17th Soyuz orbit.

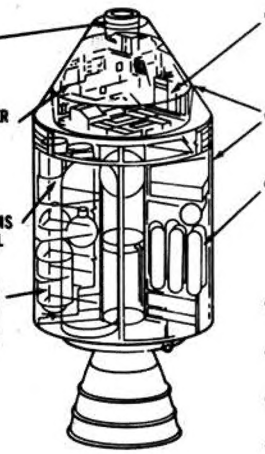
About seven hours 30 minutes after Soyuz launch (1950 GMT), the Apollo will be launched from the Kennedy Space Center in a northeasterly direction and will be inserted into a 150-by 167-km (83-by 104 mile) orbit with an inclination

* *Moscow time is obtained by adding 3 hours to Greenwich mean time. Eastern Standard Time is obtained by subtracting 5 hours from Greenwich mean time.*



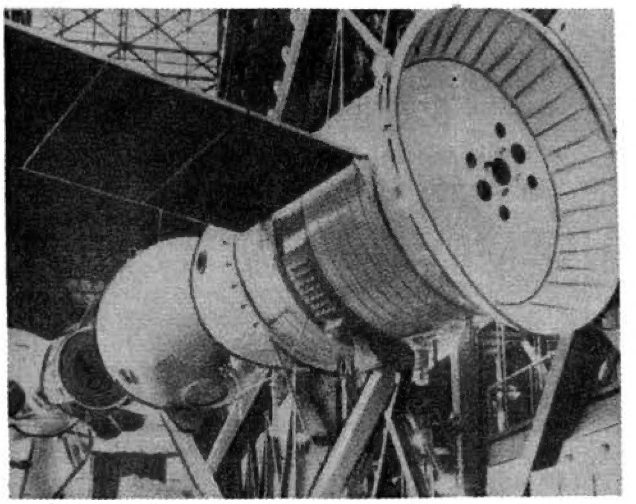
Soyuz spacecraft as modified for the ASTP mission.

NASA



ASTP Major Apollo Modifications.

National Aeronautics and Space Administration



During the Transolar tour of U.S. Space Centres in September-October 1974, B.I.S. members inspected this mock-up of the Apollo CSM and Soyuz spacecraft complete with ASTP docking module in the Vehicle Assembly Building at the John F. Kennedy Space Center, Florida. A visit was also made to the highbay area of the VAB.

National Aeronautics and Space Administration

Crew Assignments

The crew assignments for the Apollo Soyuz Test Project mission are:

U.S. Crew Assignment

	Prime	*Backup*
Commander (CDR)	Thomas P. Stafford	Alan L. Bean
Command Module Pilot (CMP)	Vance D. Brand	Ron E. Evans
Docking Module Pilot (DMP)	Donald K. Slayton	Jack R. Lousma

USSR Crew Assignment

Crew 1	Aleksey A. Leonov Valeriy N. Kubasov	Crew 3	Vladimir Dzanibekov Boris Andreyev
Crew 2	Anatoliy Filipchenko Nikolay Rukavishnikov	Crew 4	Yuri Romanenko Aleksander Ivanchenko

Apollo Soyuz Test Project Funding and Budget Request

	1973	*1974*	*1975*
Command and Service Module	$12,600,000	$32,300,000	$ 8,000,000
Docking Module and docking system	21,000,000	21,700,000	3,400,000
Experiments*	-	8,000,000	5,000,000
Launch vehicle	-	9,500,000	32,500,000
Launch operations	-	8,900,000	45,000,000
Flight support and operations	4,900,000	9,600,000	20,700,000
Total	*$38,500,000*	*$90,000,000*	*$114,600,000*

* *Reprogramming will increase total for experiments to $16,000,000.*

ASTP Major Contractors

Rockwell International Space Division Downey, California.	Command and Service Module, Docking Module, Docking System, Spacecraft Support.
Rockwell International Rocketdyne Division Canoga Park, California.	Saturn Engines and Support.
General Electric Company Valley Forge Space Center Philadelphia, Pennsylvania.	Automatic Checkout Equipment (ACE) Support. Launch Vehicle Ground Support Equipment.
Chrysler Corporation Space Division New Orleans, Louisiana.	S-IB Stage and Launch Support.
McDonnell Douglas Corporation Huntington Beach, California.	S-IVB Stage and Launch Support.
IBM Federal Systems Division Gaithersburg, Maryland.	Instrument Unit and IU Launch Support
ILC Industries Dover, Delaware.	Space Suits.
The Boeing Company Seattle, Washington.	Reliability and Quality Assurance at JSC Launch Complex 39.
Xerox Corporation Rockville, Maryland.	Digital Evaluator
Bendix Corporation Peterboro, New Jersey.	ST-124 Platform.

Apollo/Soyuz Test Mission Radio Communications links.

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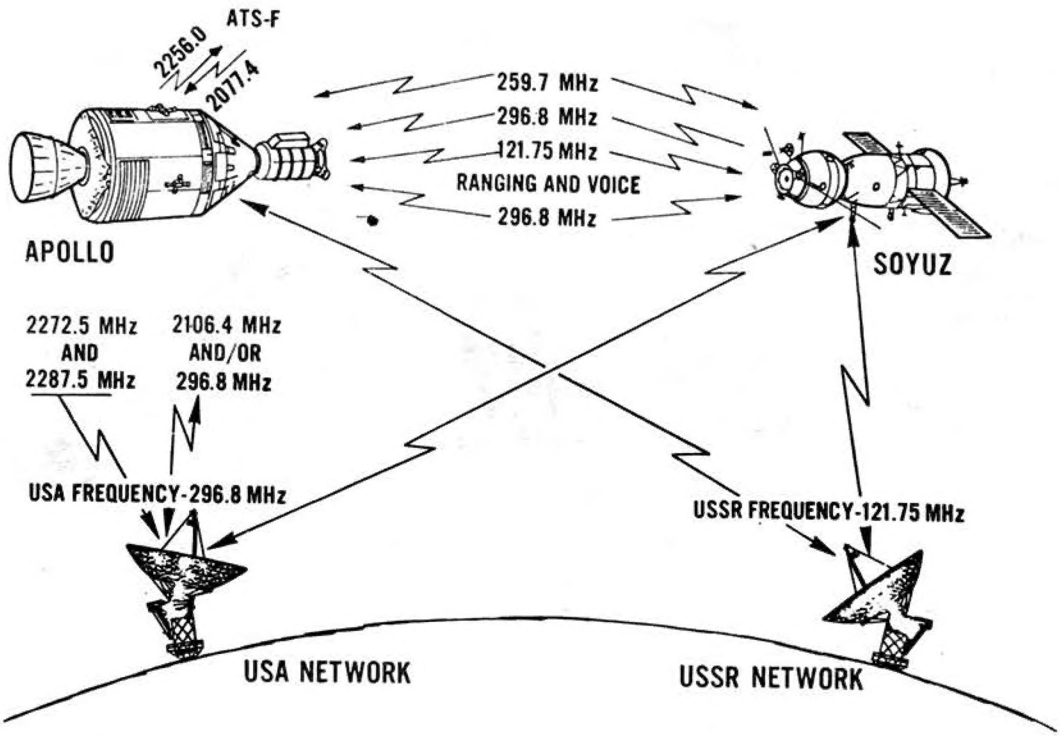
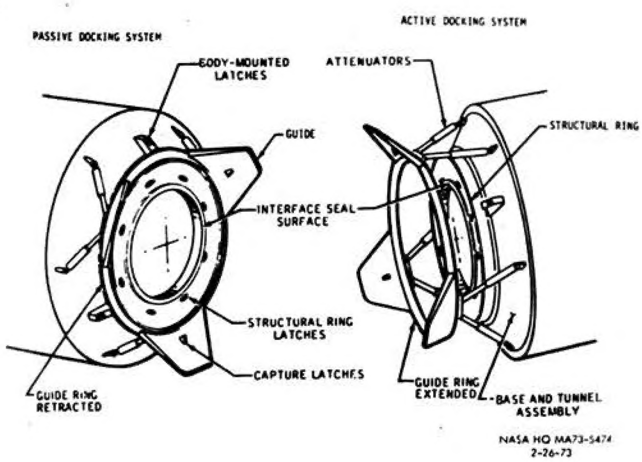


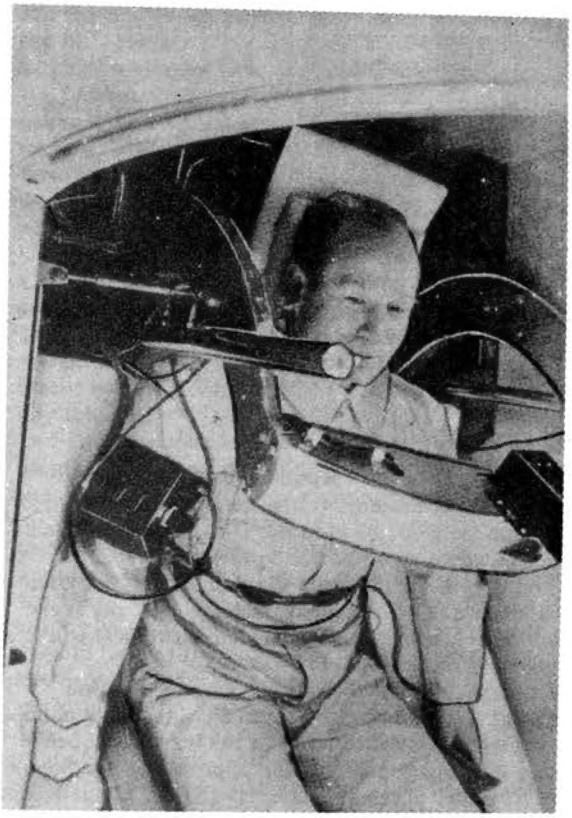
Below. New ASTP Compatible Docking System.



U.S. Space Vehicle Configuration

The Saturn IB launch vehicle, Apollo spacecraft, and other major hardware designed for the Apollo Soyuz Test Project mission will be as follows:

	Designation Numbers	
Configuration	*Prime*	*Back-up*
First Stage	S-IB-210	S-IB-209
Second Stage	S-IVB-210	S-IVB-209
Instrument Unit	S-IU-210	S-IU-209
Spacecraft – L/V Adapter	SLA-18	SLA-22
Docking Module	DM-2	DM-1
Docking System	DS-5	DS-7
Service Module	SM-111	SM-119
Command Module	CM-111	CM-119
Launch Complex	LC-39B	LC-39B

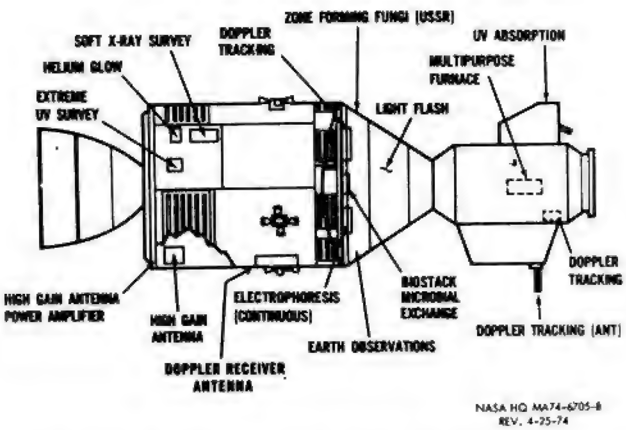


Alexei Leonov in the centrifuge at the Cosmonauts' Training Centre, Star City.

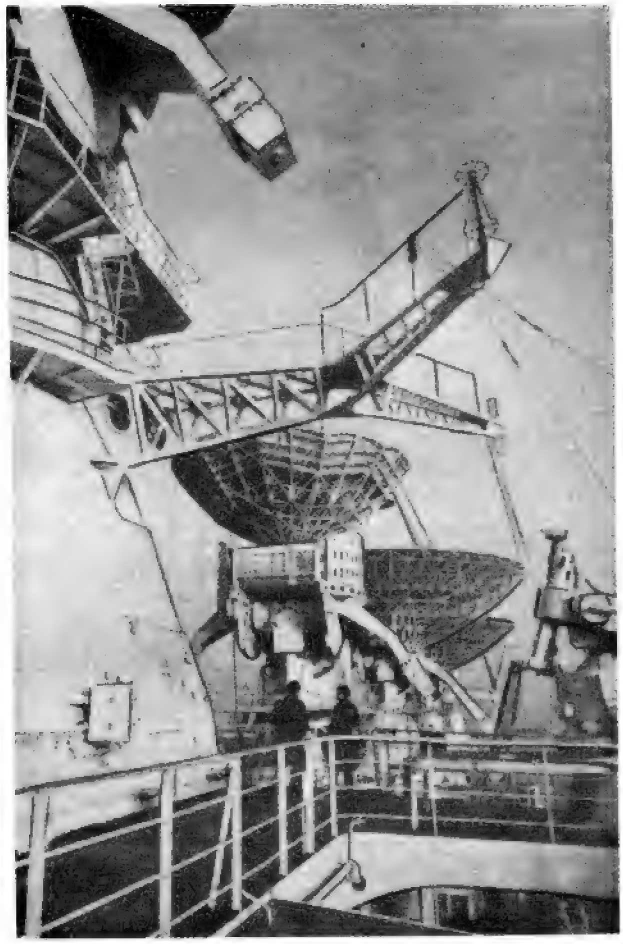
Novosti Press Agency

Valeriy Kubasov checks over the controls in the Soyuz training capsule.

Novosti Press Agency



Experiments and ATS-6 location schematic, see page 6. Communications with Houston and Kalinin control centres will be maintained with the help of tracking ships, aircraft and Molniya and ATS-6 satellites.



The tracking and communications ship *Cosmonaut Yuri Gagarin* in the port of Odessa.

Novosti Press Agency

of 51.8°. About 1 hour after Apollo orbit insertion, the Apollo CSM will begin the transposition and docking procedure to extract the Docking Module (DM) from the launch vehicle. The extraction of the DM will be completed by 9 hours 14 minutes Soyuz, Ground Elapsed Time (GET). An evasive manoeuvre of 1 metre per second (3.3 ft. per sec.) posigrade to avoid recontact with the launch vehicle will raise apogee to about 167 km (104 miles).

The Apollo spacecraft will perform a circularization manoeuvre at third apogee to establish a controlled Apollo rendezvous manoeuvre sequence. The rendezvous sequence establishes a standard geometry final approach to the Soyuz spacecraft. The first phasing manoeuvre (NC1), which occurs at about 13 hours 12 minutes Soyuz GET, is an in-plane, horizontal manoeuvre designed to adjust the rate of change of the phase angle by changing the orbital period. If necessary, a plane change manoeuvre (NPC) will be performed after NC1 and before the second phasing manoeuvre to place the Apollo in plane with the Soyuz at rendezvous. The plane change manoeuvre will complete the first day of manoeuvre activities for each crew.

The Soyuz circularization manoeuvre to establish the final rendezvous and docking orbit will occur on the 17th Soyuz orbit. Eight hours later, at about 32 hours 22 minutes, a nominally zero phasing correction manoeuvre (PCM) is scheduled for the Apollo which would correct for any phasing errors which might have occurred at NC1 and at the Soyuz circularization manoeuvre. The second phasing manoeuvre (NC2), at 48 hours 34 minutes Soyuz GET, is an in-plane, horizontal manoeuvre to adjust the altitude difference with respect to the Soyuz. Following NC2, the corrective combination manoeuvre (NCC) is performed at 49 hours and 18 minutes Soyuz GET. The NCC manoeuvre controls the phasing, the differential altitude, and the differential plane between the two spacecraft at the coelliptic manoeuvre point. Finally, the coelliptic manoeuvre (NSR), at 49 hours and 55 minutes Soyuz GET, establishes an orbit which maintains a near constant differential altitude between the two spacecraft.

SKYLAB: THE THREE MONTH VIGIL

By David Baker

PART THREE

Concluded from December 1974 issue, p. 461.

With the experience of SL-III behind them, flight planners had been too optimistic and crowded each day with a multitude of tasks without due consideration for the minor irritating problems constantly occurring on the big space station. It should be borne in mind that Skylab was designed from the outset as an experimental laboratory, conceived for just this very function. By applying a meaningful learning curve, through experience in Skylab, mission planners would be in a better posture for future, more permanent facilities.

For the crew's part, they had remained silent too long, attempting to chase every planned objective without discussing each minor problem with the ground. In their defence it must be said that they had exhibited a reluctance to visibly de-scale the experiment programme and had chosen to work as hard as they had physically felt able with the constant threat of an early abort due to CMG problems. The air-to-ground conference on these matters was conducted in a very understanding manner and a high regard for the problems of each group by personnel on the ground and the crew in orbit. With Skylab IV well into the second half of its flight a new mood seized mission control and prospects looked good for a satisfactory conclusion to the record-breaking voyage.

New Year in Orbit

By 31 December 1973, SL-IV was well into the second half of its 84 day mission. The only cause for concern centred on the control moment gyros. Wheel No. 1 had seized early in flight, throwing all momentum storage on the other two and increasing the use of TACS (Thruster Attitude Control System) nitrogen gas. Wheel number 2 had been indicating a minor malfunction, with slight reductions in speed, but if it held up Skylab could use an average 320 lb/sec/day TACS gas and still keep the 6,000 lb/sec contingency margin. If it failed the crew would be ordered down, probably within 10 days.

Crew performance had been running mid-way between that of SL-II and SL-III and a heart to heart discussion with ground controllers on Day 45 promised to improve the record. For their part, Houston reduced preparation time on the Earth resources experiments by 30% and relaxed the need for two men to monitor all manoeuvres. Day 46 (31 December 1973) went without notable change in the systems situation and the crew began their rest period at 10:00 p.m. CST. Houston was going on to Daylight Saving Time on 6 January but because of early morning Earth resources scans the crew made their adjustment during the night of 31 Dec/1 Jan. This resulted in a 1 hr. reduction in sleep time and all three astronauts were up by 5:00 a.m. to begin the EREP run at 7:13. A slight increase in TACS was necessitated when Pogue moved the cluster to a local vertical attitude 1 hr. too soon. Some 170 lb/sec gas was used *versus* 150 lb/sec predicted. During the day the ATM control and display panel coolant loop was flushed out. It had recently showed fluctuations of 30 lb/hr flow rate, dropping as low as 160 lb/hr before servicing. It was soon back up to 260 lb/hr.

Day 48 was a recreation day for the crew, and they slept in for an extra 2 hr. At 10:30 a.m. CMG No. 2 again showed signs of distress when wheel speed dropped from 8,912 r.p.m. to 8,870-8,881 r.p.m., this occurring at a bearing temperature of 75°F. Shortly after lunch a press conference was held with Houston, followed by a science conference on experiment status. All three astronauts began their sleep period at 9:00 p.m. for a wake-up call at 3:40 a.m. on Day 49 to catch an Earth resources opportunity beginning at 4:39. Using only the Earth Terrain Camera the 12 min. pass covered a 3,400 mile strip over the Sudan and Iran. At 5:48 a.m. another speed reduction was observed on CMG-2 but the repetitive nature of the distress alarms seemed to indicate that the wheel was holding up better than CMG-1 which had failed completely after only half the number of problems seen on wheel number 2. At 7:45 a.m. power was lost from the ATM control and display console, preventing accurate pointing of the telescopes and operation of the digital address system. This was soon rectified. During the day the crew found more empty urine bags, missing for a week now, but 23 were still at large. Because of this Mission Control advised the crew to sample once every 36 hr. instead of daily as before, thus using fewer bags and providing continuous sampling right up to the end of the flight. Sleep began at 9:00 p.m. CST because the crew had made their own Daylight Time adjustment several days before. Within 2 days the ground controllers would take their clocks forward 1 hr. and put the official sleep time back on a 10:00 p.m. – 6:00 a.m. basis, keeping pace with the rest of the USA.

Up at 5:00 a.m. on Day 50 the crew performed the usual experiments and used the liquid-gas separator to cleanse the ATM control panel coolant loop again (flushed last on Day 47). During the day the Prime Recovery Ship *U.S.S. New Orleans* slipped its berth at San Diego and made for Pearl Harbour, scheduled to arrive on Day 57. By Day 59 (13 January 1974) the medical laboratory would arrive and put the full recovery capability into action – just in case. Day 51 came and went in uneventful fashion but a roll manoeuvre for Kohoutek observations was curtailed due to the high beta angles with the Sun. Temperatures were expected to reach 220°F on the exposed hull of the space station, still far below the 350°F which could cause outgassing from insulation on the interior face. During the night, which began for the crew at 9:00 p.m. CST, all clocks in the USA were put forward 1 hr. and the astronauts woke up at 6:00 a.m. CDT after an 8 hr. sleep. About 17,900 lb/sec TACS gas remained in the workshop's attitude control tanks, with 11,900 lb/sec available for use. The balance consitutes the margin reserved for an additional stay aboard Skylab if a rescue vehicle has to be readied at the very end of the 84 day mission.

Earth resources activity, ATM work and corollary experiments were the order of business and during the afternoon the crew used the ATM telescope to scan Kohoutek for the last time. Day 53 brought 28.5 man/hr. of scientific activity to Skylab, the heaviest work load for some time despite another CMG-2 wheel speed reduction and a massive 965 lb/sec use of TACS gas when Gibson read the Earth resources manoeuvre pad incorrectly. At the end of the day only 16,800 lb/sec total remained. Next day the crew did even better, putting in some 30 man/hr. of science, repeating the performance on Day 55. Following 24 hr. of recreation on Day 56, Day 57 was notable for losing some Earth resources film due to wrong switch positions and minor fluctuations in the ATM control panel coolant loop. Some concern was being expressed over the high beta angles and the consequent rise in temperatures due to 100% sunlight on all orbits by Day 60. Lights had already been turned down to reduce heat output internally and with both primary and secondary coolant loops turned on within the next few days the tem-

peratures could be constrained to a reasonably comfortable 75-82°F. A weekly status review began on Day 56 with a 7 day go-ahead passed up to the crew. To date (end of Day 56) about 62% of the original schedule had been completed. In some areas crew performance was exceeding that of the record breaking SL-III. Medical activity showed better responses on the cardiovascular system although slightly increased heart rates were logged for this crew as expected. Gibson and Pogue had each lost 4-5 lb. in weight during the first 10 days of the mission and were holding at that point, although Carr had actually gained 0.5 lb. Accurate measurements of the body fluid loss appeared to indicate a re-distribution to the torso and upper extremities rather than a complete volumetric reduction and, again as expected, body height had increased by 1.5-2 in. due to unloading of the vertebral column.

Endurance Record is Broken

Day 58 (12 January 1974) showed increasing temperatures due to the high beta angles whilst on the ground a record 15,000 persons toured the Johnson Space Center at Houston, Texas. Day 59 provided an opportunity to use the UV photographic equipment, primarily intended for airglow analysis, on Kohoutek which was now climbing away from the Sun with its 10 million mile long dust tail. An Earth resources run was cancelled due to bad weather. Day 60 made this up with two EREP passes during the morning, a UV Stellar Astronomy manoeuvre and a UV Electronographic camera scan of Kohoutek during the late evening. Nevertheless, success was tarnished by another CMG-2 distress at 5:00 p.m., and indications of trouble in CMG-3. The wheel speed transducer had failed long ago but electric currents rose and seemed to duplicate the trouble with wheel 2. It mattered little. If one more wheel failed the third could not possibly control attitude by itself. Despite this, at precisely 8:10:26.5 CDT SL-IV equalled the record 59 days 11 hr. 9 min. 3 sec. set up by SL-III only months before and swept on to break new records that would stand, in NASA archives at least, for perhaps a decade or more. In space, Skylab was coming to the end of its 3,543rd revolution since launch on 14 May 1973.

During the next two days temperatures in the orbiting workshop continued to rise, reaching 80°F by Day 62. Skylab was now in perpetual sunlight and manoeuvres were severely curtailed. The shade erected by SL-III crewmen was covering only the upper surface of the hull. Day 61 provided an opportunity for Carr and Pogue to use the foot-controlled manoeuvring device and still the CMG-2 wheel gave up the occasional distress. Day 62 brought low airflow rates of 152 ft^3/min and Pogue pulled a vacuum on the heat exchanger to restore the full value of 160 ft^3/min. The ducts would be cleaned out the following day to eliminate contamination. Day 63 showed up the continuing fluctuations in CMG-2 wheel speed, dropping at one point to a new low of only 8,800 r.p.m. Despite this Carr and Pogue worked at manoeuvrability tests with the M509 experiment during the afternoon hours.

By early morning on Day 64 the internal temperatures reached 82°F, but now the high beta angles were coming down and the workshop began to experience the effect of an eclipsing Earth on the direct sunlight. Despite being a day off the three astronauts accomplished nearly 10 man/hr of science including ATM scans and an Earth resources pass. By now SL-IV had completed 278 man/hr of medical experiments, 266 man/hr of ATM work, 247 man/hr of corollary activity (of which 91 hr. were on Kohoutek) and 52 man/hr of comet observations with the ATM telescopes. The morning of Day 65 required a corrective procedure from the crew. An airlock purge fitting had been left in the wrong position causing a slight propulsive venting of the gaseous atmosphere which resulted in the expulsion of 20 lb/sec of TACS gas for attitude corrections. More CMG-2 anomalies continued with oscillating speeds between 8,870 and 8,900 r.p.m. During the evening an Airlock Module tape recorder was changed, having failed after 1,446 hr. of use *versus* the specified design limit of 800 hr.

Preparing for Emergency Recovery

Another crew error crept in on Day 66, when Pogue inadvertently turned off the Multispectral camera during an Earth resources run over the United States. During the afternoon more Astronaut Manoeuvring unit tests were made on M509 and by 7:22 p.m. CMG-2 experienced its 27th glitch, lasting 1 hr. Experiments went on but the CMG-2 wheel was now giving considerable cause for anxiety as anomalies came with increasing frequency and duration. Despite this a service module RCS trim burn was made at 8:12 on Day 67, shifting the ground track 3.5 miles west by Day 70. Then, on Day 68, with CMG-2 in almost continual distress, an EREP run was cancelled and ground controllers developed a contingency procedure in the event it stopped completely. Almost immediately the recovery force was ordered back into San Diego for fresh supplies so that it could be active from Day 73, but ideal recovery times would still fall on Days, 75, 80 and 85 due to the migration of the Skylab orbit. For emergency reasons the recovery ships would move to alternate recovery sites on intervening days.

The sequence of operations designed to bring the mission to a safe conclusion if CMG-2 failed completely, went as follows. The entire cluster would immediately start using the TACS gas for attitude control in solar inertial orientation (at 700 lb/sec/rev) until the crew could power up the Apollo thrusters in wide deadband mode. This would provide an 8-day capability while still retaining a contingency reserve. If CMG-2 still remained unoperable it would be powered down completely with attitude control retained by the RCS thrusters on Apollo, but in a quasi-inertial mode providing some 15 days of on-orbit capability. The crew would then patch a quasi-inertial attitude programme into the TACS, determine how much was left and decide on a recovery from the gas remaining.

By Day 69 engineers were huddled over conference tables at the Marshall Space Flight Center, desparately trying to work out a solution. A distress that began at 00:35 a.m. was still in progress when the crew went to bed and by wake-up time the next day wheel speed had dropped to 8,829 r.p.m. The general concensus agreed that CMG-2 appeared to be caving in at last. An EREP pass on Day 68 had already been cancelled, but a less demanding run had been held later in the afternoon, with another run cancelled on Day 69. To make matters worse, a second EREP scan had to be cancelled due to weather. Engineers were split in opinion. Some thought local vertical manoeuvres (necessary for EREP runs) were harmful, others thought not. Now there was only 16,032 lb/sec TACS left in the workshop tanks, but only 10,032 lb/sec of that was usable due to the requirement for a contingency margin. All other systems were holding

Third Skylab boarding party: *left to right,* Edward G. Gibson; Gerald P. Carr, and William R. Pogue. Behind them is their Saturn I B. rocket at launch complex 39B.

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up well, with 2,200 lb. of water left and nearly 3,500 lb. of the life-giving oxygen/nitrogen gas. Cooling lines were operating as expected but the ATM control panel plumbing again showed fluctuations in pressure. Earth resources runs were suffering heavily from the spasmodic anomalies to CMG-2. By Day 79 all EREP opportunities would be lost yet only 54% of Multispectral camera film, and 74% of Earth Terrain Camera film, had been used. The Infrared Spectrometer had used 75% of its 16mm footage and the Multispectral Scanner only 71%. Weather, CMG-2 problems and a late start to the mission had all played their part in reducing the data take.

An EREP run was accomplished on Day 70, with CMG-2 still in distressed condition that began the previous morning, and again on Day 71. With the crew asleep the three astronauts exceeded Alan Bean's space flight duration record of 69 days 15 hr. 45 min. 29 sec. at precisely 00:46:52 CDT. During the day Skylab was rolled 40° for UV Electronographic camera views of Kohoutek, before an early start to the night at 9:00 p.m. Although up at 7:00 a.m. on Day 72 they had budgeted a 10 hr. night, due to them for their rest day. However, an EREP run was accomplished and at 8:08 the UV camera was used to photograph exhaust trails of a DoD rocket launch over the U.S.

Day 73 brought two more Earth resources runs and a total 28 man/hr of science. CMG-2 speed dropped dangerously low, falling to within 8 r.p.m. of the shut-down value, but soon levelled back again, at the new "norm" of 8,850 r.p.m. Less than 15,700 lb/sec TACS remained and Skylab was budgeted to a maximum 700 lb/sec/day to reach the end of the full mission with a 10-day rescue margin. The ceiling on gas usage had been less than half this value 30 days earlier.

At 9:14 CDT the orbiting cluster, in a 267.9 x 274. 8 sm orbit, was passing over a point on the Earth centred at 6°43'46"N x 1°12'33"W, 274 miles high. The significance of this is that it was also passing within 3.5 miles of OV32, a DoD satellite launched on 28 October 1966. OV-32 was in an orbit of 210 x 483.4 sm, inclined 82°. Potential impact speed of the two vehicles was a frightening 35,000 m.p.h.!

Next day, Day 74, the crew accomplished nearly 29 man/hr of science and even CMG-2 seemed to be giving Skylab a reprieve. Speed, at 8,870 r.p.m., was the highest since the current distress began at 00:35 a.m. on Day 69. During the night the CMG bearings were exposed to full Sun and temperatures decreased, electric current fell and wheel speed increased to 8,900 r.p.m., only to drop back again later. Also, on Day 76, the ATM control panel pumps fluctuated but this was no problem and redundant hardware saved the day. Meanwhile, on Day 75, the UV Scanning Polychromator Spectroheliometer (an ATM instrument) was pointed at *Gamma Velorum* in an attempt to confirm that UV emissions below 912 Å observed by Mariner 10 were in fact coming from this source.

Although scheduled as a day off, Day 77 provided an opportunity for Earth resources work, taken during the morning with an EREP run. Day 78 saw the last full operational use of Skylab as an experiment facility. At 11:52 a.m. the last EREP pass began and it was all over just 25 min. later. The previous day the sensors had performed a full 360° global scan of the Earth for long-arc geoid measurements. By evening, Carr had used the UV Electronographic camera on Kohoutek for the last time. Medically, all seemed well with the crew as they began their last week in space. Very little change had been noticed during the past month and several values were indicating a slight improvement on weight loss, heart response and muscular atrophy. In anticipation of an impending shutdown the shower unit failed on Day 77, immediately followed by the visual tracking system on the Infrared Spectrometer. But CMG-2 was still hanging on and refusing to cave in. In and out of distress continually, the wheel was only just holding up and engineers expected a complete failure any hour.

Last ATM Operations

Day 79 brought the last manned ATM operations, performed by Gibson during the evening, and the first of the Apollo CSM checks in preparation for the return to Earth. During the afternoon all three astronauts readied equipment for the last EVA. Up at 6:00 a.m. on Day 80, Carr and Gibson donned their pressure garments and prepared to exit the Airlock Module. The EVA, last in NASA manned space flight this decade, brought to a close the remarkable accomplishments of all three Skylab teams in going outside their space station to repair and service the external systems. It was fitting it should be made through a hatch left over from the Gemini programme.

Leaving Skylab at 10:19 a.m. they swiftly retrieved film from the White Light Coronograph, X-ray Spectrographic Telescope, and dual X-ray telescopes, H-alpha telescopes and the XUV Spectrograph/Spectroheliograph. The Coronograph Contamination experiment was operated and spectral photographs of the Sun were taken with the X-ray/UV camera. Modules from the Trans-Uranic Cosmic Ray, Magnetospheric Particle Composition and Thermal Control Coatings experiments were also retrieved and brought inside for return to Earth, along with a clipboard of solar sail material from the ATM truss. Finally, a set of Particle Collection cassettes was put out on the ATM Sun shield for retrieval on a future re-visit, if such a re-visit is ever made. At 3:38 p.m. the EVA was over and the crew were back inside the space station. TACS usage during the day amounted to 965 lb/sec but this still left about 13,000 lb/sec available, or 7,000 lb/sec above the redline for the balance of the mission.

Days 81 and 82 were devoted to stowing equipment and moving items from the workshop to the Apollo command

module. Several hours were spent in burning 30 different materials in the vacuum chamber, an experiment left until last due to possible contamination from venting the chamber to space. This was performed on Day 81. Battery tests on the Power Conditioning Groups fed from the single workshop solar array showed 33.5 amp/hr *versus* the expected 26 amp/hr. By now the bearing temperatures in CMG-2 were high enough to maintain constant 75°F and manual heater management was terminated.

The last orbit trim burn was made at 3:48 p.m. on Day 83, a 180 sec., 12 ft/sec burn from four RCS jets on the service module. This raised the orbit to 246 x 235 nm, ensuring a 9 year lifetime for the Skylab cluster. More deactivation and transfers filled the day and the crew went to bed at 8:00 p.m., getting up at 4:00 a.m. on Day 84. It was to be a short day, lasting just 9 hr. All the prime systems had been turned off including the oxygen/nitrogen supply. wardroom water and the waste management section. The Apollo command module was ready and waiting, completely powered up with the exception of the environmental control system. As if to signify a reluctance at disgorging the last crew, CMG-2 came completely out of distress and wheel speed rose to 8,900 r.p.m.! All the Charger Battery Regulator Modules tested showed a capacity of 10.5 amp/hr. Very little degradation had set in as SL-III tests showed 12 amp/hr back in September 1973.

At 1:00 p.m. on Day 84 the crew began their last sleep period aboard Skylab, getting up at a little before 9:00 a.m. Final closeout activities kept them busy until midnight Houston time but before leaving the Multiple Docking Adapter a bag was left for possible retrieval years hence. It contained food samples, clothing and tether material, a surgical glove, a heat exchanger fan, a fire sensor panel, four film samples, a roll of teleprinter paper, Multispectral camera filters, communications cords, four flight data files and two electric cables. All the interior hatches were left open, pinned back on latches, and at 1:20 a.m. CDT the Multiple Docking Adapter Hatch was installed.

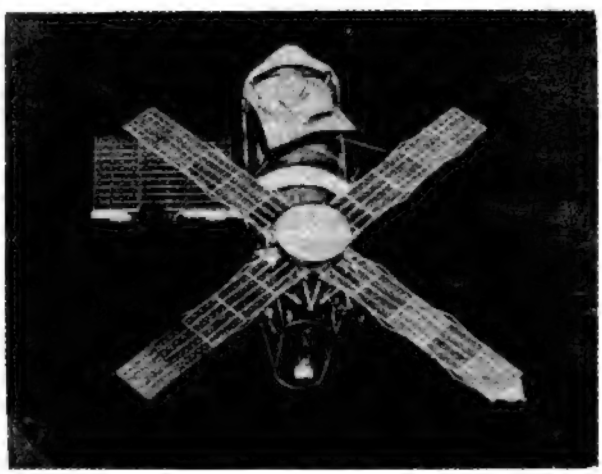
"Farewell to Skylab"

To all who had been concerned with the first true laboratory in space this had to be the emotional moment. A dozen red roses arrived at Mission Control, sent by long time admirer Miss Cindy Diane, and thoughts turned again to the dark hours of 14 May 1973, when all seemed lost and Skylab appeared doomed to an inglorious fate. Now, after more than 171 days of manned operations, the last crew was coming home. At precisely 5:34 CDT Apollo slipped away from the docking cone and began a last tour of inspection, moving round the giant assembly taking pictures. At 6:00:07 the RCS thrusters fired for 12 sec. to change the Apollo CSM orbit from 234 x 246 nm to 232 x 246 nm. This separation manoeuvre put the CSM two miles away from Skylab when, at 6:32:54 CDT, the SPS engine was fired for 12 sec., slowing Apollo by 295 ft/sec. Now in an orbit of 232 x 90.5 nm the spacecraft was set up for the de-orbit burn.

At precisely 9:35:59 a.m. CDT the SPS engine fired again, this time for 8 sec., reducing the speed by 185 ft/sec. Just 1 hr. before, at 8:35 a.m., a leak had been detected in the No. 2 helium line and pressure fell from 4,150 psi to 3,450 psi before the loop was isolated. An instruction was now read up to the crew whereby they could use the emergency O_2 masks on re-entry if they smelled a "fishy" or acid odour. This would indicate a fuel or oxidiser leak respectively. As it turned out the leak came from a 0.01-in. perforation of the helium line itself. Before separation of the service module a procedural error resulted in wrong circuit breaker settings and entry attitude was obtained by manual control in pitch and yaw. Nevertheless, all went well and the 12,134 lb. command module splashed down into the Pacific at precisely 10:16:55 CDT (15:16:55 GMT). It was 8 February 1974 and SL-IV had set the new space flight endurance record at 84 days 1 hr. 15 min. 32 sec. On board the command module, temporarily upside down, was 1,718 lb. of equipment, film and tape. This compares with 1,649 lb. on SL-III and 1,388 lb. on SL-II.

In all, this last mission had travelled 30,561,000 miles and exceeded the scientific return of any previous flight. When the operations began on 14 May 1973, the three visits were to have provided a total manned duration of 140 days spread over 240 workshop days in orbit. At SL-IV splashdown the three teams of astronauts had lived aboard Skylab for more than 171 days spread over 271 days of Skylab operations. From a predicted 565 hr. of ATM work the three teams had logged 755 hr. and from an expected 701 hr. of medical tests they had contributed 822. Materials experiments, planned to occupy 10 hr., had accumulated 32 hr. of data, and astrophysics work had grown from a predicted 168 hr. to 412. Even student experiments had risen from 44 hr. scheduled time to 56 hr. operational time.

But totals for the SL-IV flight alone had not reached the level anticipated before the mission began. Out of a predicted 52 Earth resources passes only 45 were accomplished although most of the responsibility for the deficit lay in the late launch, removing some scheduled opportunities, the CMG-2 problems and weather cancellations. It is opportune to point out here that although several passes were made early in the flight with incorrect filter settings all the task site objectives had been repeated by the end of the mission and very little was lost through crew error. Excluding the H-alpha views, ATM work contributed more than 46,000 frames, 2,000 more than SL-III, and 60,000 UV Spectro-



An overhead view of the Skylab space station photographed from the Skylab 2 CSM during the final fly around inspection. Note the deployed parasol solar shield which shades the Orbital Workshop where the micrometeoroid shield is missing.

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heliometer rasters, compared with 40,000 on SL-III. Medical experiments had contributed 348 man/hr. of work and nothing had been lost.

All in all SL-IV was a resounding success and many critics of manned space flight have been confounded by the versatility, determination and results obtained by controllers on the ground in meeting both systems and crew problems head on. Resolving many of the operational difficulties early in the programme, engineers on the ground worked with astronauts in space to effectively maintain the capability foreseen in the planning stages years before. When Skylab became vacant on 8 February 1974, the consumables were in good condition. About 3,341 lb. of O_2/N_2 remained and at a normal usage rate of 15 lb/day this could have supported an additional 212 days of manned flight. The limiting gas was O_2, using 13 lb/day with 2,764 lb. remaining. The leak free integrity of Skylab was far better than prelaunch predictions indicated, hence the large balance left over. Water supplies were also on the high side, with 1,710 lb. left in the tanks. At an average flow rate of 19 lb/day this could have supported a 90 day mission to depletion. But TACS gas, the nitrogen stored beneath the radiator at the rear of the workshop, would be the limiting factor. Only 12,000 lb/sec remained and of this only 6,000 lb/sec could be used if a requirement existed for emergency reserves. Nevertheless, at SL-IV rates it could have lasted an extra 30 days, assuming of course that the CMG-2 wheel continued to operate preventing the use of TACS as the primary method of attitude control.

Skylab is Powered Down

Immediately after the crew began their return to Earth engineers at Mission Control in Houston went through a series of engineering tests. These included an attempt to power up CMG-1, the failed control moment wheel, but indications were that the bearings were completely siezed up. Electrical tests were run, and all Airlock Module batteries were discharged to 30 volts one at a time, followed by checks on the coolant loop valves. The redundant ATM, Pulse Code Modulation equipment, not used on the three missions, was tested and showed an "as new" condition. Then began the long power down sequence. First the workshop was vented to 2 lb/in^2. It would take 2 months to evacuate the O_2/N_2 atmosphere completely. Following this operation the workshop was positioned in a gravity-gradient stabilisation mode whereby the longitudinal axis is pointing earthward with the Multiple Docking Adapter facing up. Then the TACS system was turned off, the CMG's were shut down and all the electrical loads were removed and switched off. Finally, at 15:09:05 CDT (20:09:05 GMT) on Saturday 9 February 1974 the last command was sent to turn off the telemetry. As the command receivers are hard wired to the TM electrics this effectively killed the workshop and removed any possibility of resurrecting the systems.

And so, with the shutdown of Mission Control it was all over. The results were staggering. With 45 miles of magnetic tape, 2,500 ft^2 of Earth resources views and more than 200,000 images of the Sun, scientists will be kept busy for several years. Medical science too will take delight from more than 5 miles of vectorcardiogram data and the 801 man/hr of tests accumulated by nine men who, in just nine months, extended space flight from three weeks to three months. But Skylab is more than all of this. Accumulating more time in space than all NASA manned space flights before it, Skylab has shown that man has a purpose in space. If that purpose is measured against the dictates of a slide rule, or the cold economics of a balance sheet, the point is lost.

Instead, it has shown that space has become a part of Man's world (to quote Mr. Richard Nixon) and that whatever he may accomplish in the dark reaches of an intergalactic void his real destiny lies in caring for his own kind. Today, our society is incapable of accepting these values but were it not for the force behind Skylab we would never have known what the future might bring. Our children will inherit a world where Earth and all its resources are of prime importance to the future of all mankind. It is enough to know that our own generation has not been found wanting.

"COCKROACH" ON MARS

Soviet scientists are developing an insect-like robot with a laser "eye" designed to roam the valleys of Mars to analyse the soil and search for life. An armoured version might be used eventually to explore the surface of Venus.

Development of the six-legged robot began with theoretical studies at the Institute of Applied Mathematics after wheels and catapillar tracks had been found inferior to legs for surmounting obstacles and climbing slopes in uncharted terrain.

To help them work out appropriate control movement and leg actions, the scientists built an electronic simulator called "Cockroach". A computer was used to prove the control mechanism which will be essential to the robot in picking its way over uncharted obstacles without coming to grief.

Georgi Babakin, one of the designers of the Lunokhod eight-wheeled moon rovers, points out that the "drivers" of such vehicles at Soviet mission control could correct their course by radio in three seconds. Elsewhere in the Solar System the delay would be at least 10 minutes which constitutes a major design problem.

The robot explorer for Mars or Venus, therefore, must be able to "think" for itself. It will have an elementary machine intelligence with overriding Earth control.

To achieve this a laser-eye scans ahead. When it encounters an obstacle, the robot stops automatically at a safe distance and feeds data to its electronic brain which works out an avoidance path. If the problem is too difficult it signals Earth for further instructions.

Already, two of the Institute's scientists Dmitry Okhotsimsky and Alexander Platonov can demonstrate on a monitor screen linked to a computer a schematic of a six-legged robot crossing crevasses, climbing slopes and getting out of craters.

In the meantime a prototype six-legged walker – a precursor of the real Cockroach to be – has been going through its paces at the Institute of Problems of Information Communication. Helping to develop the basic technology at the Moscow University Institute of Mechanics is a device called Rickshaw. This has two wheels and two legs, the legs being test units for the walking robot.

A *Novosti* report also links the work with the Institute of Aviation Instrument Makers in Leningrad. Apparently several institutions and laboratories are participating in the design and construction, and quite soon the Russians expect to have a more developed version taking its first steps on Earth. Maximum walking speed will be 3.7 m.p.h. (6 km/hr).

SPACE REPORT

A regular monthly review of Space Events and Technical Trends

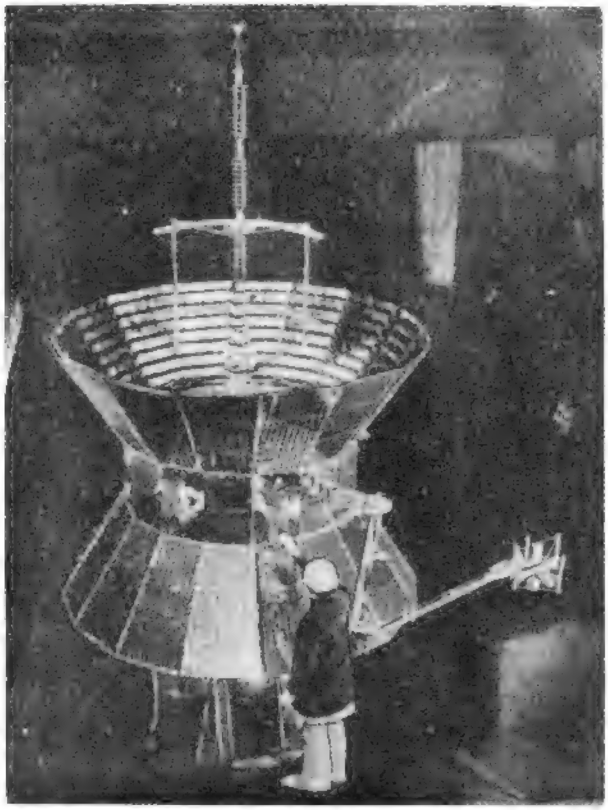
HELIOS THERMAL TEST

Heat equivalent to that of 11 Suns has been produced for the first time in a large space simulator at the Jet Propulsion Laboratory. This was done in tests conducted on a prototype of the Helios-A spacecraft being prepared for launching from Kennedy Space Center to travel within 28 million miles of the Sun, 10 million miles closer than a man-made object has gone before.

During the tests, parts of the spacecraft reached 700° F. (370° C.). After five days of testing, the German-designed Helios was proclaimed ready to withstand the extreme temperatures it will encounter during its unprecedented journey.

Previous high intensity achieved in the simulator was six and a half Suns, accomplished in testing Mariner 10 prior to its successful trip to Mercury. Project Managers Ants Kutzer and Gilbert W. Ousley said the JPL facility was the only one capable of running the necessary tests for Helios. Kutzer is associated with the West German Association for Space Exploration, Ousley with Goddard Space Flight Center.

Helios-A was launched jointly by the United States and West Germany. A second craft, Helios-B, is scheduled for launch in late 1975.



Helios Sun probe, to be launched shortly from the John F. Kennedy Space Center, Florida, by a Titan IIIE-Centaur-TE 364-4. The 770 lb. (350 kg) spacecraft built in West Germany, will carry 11 experiments to examine conditions only 28 million miles (45 million km) from the Sun, well within the orbit of Mercury (see *Spaceflight* January 1974 pp. 5-6).

Messerschmitt-Bölkow-Blohm

NASA'S SMART ROBOT

Equipped with metal arms and hands, a visual system of two television cameras and a laser, wheels for legs and with thousands of instructions programmed into its computer brain, a smart robot is being developed for NASA at the Jet Propulsion Laboratory and the California Institute of Technology. The immediate objective, according to Dr. William M. Whitney, technical leader of JPL's robot programme, is to prove the feasibility of doing scientific exploratory work on a planet like Mars without constantly having to send instructions to tell an exploratory device what to do.

Dr. Meir Weinstein, visiting assistant professor of computer science at Caltech and in charge of one portion of the computer programme which gives the robot an "artificial intelligence", said that eventually similar robots may be put to work on varieties of jobs on Earth in environments that are hostile to man, such as mining the sea bottom, working in a radioactive environment, or fighting a fire.

"When the machine is complete", said Dr. Whitney, who is manager of JPL's astrionics research section, "it will be able to analyse a scene optically and extract information from it. It will be able to work in a complex, realistic environment and will make some choices of its own. It will be able to pick up rocks and to move around boulders without hitting them. It must have a survival ability that will recognise craters and cliffs and will enable it to move safely through rough terrain".

It will be programmed to estimate the weight and density of rocks that it does pick up, and will send the information back to the human operator. Perhaps it will be able to develop plans for carrying out some tasks.

The programme was initiated by NASA to accomplish two objectives: One, to gain expertise in the art of building robot machines. Two, to determine what capabilities such machines must have to be useful in planetary exploration.

"There is great interest in this field of robotics", Weinstein said. "The National Science Foundation is funding studies of industrial automation robots. Such robots with greater efficiency might help the United States compete with foreign production and solve some of the social and environmental problems. Such robots could perform some monotonous jobs for which it is difficult to recruit workers".

Dr. Weinstein and his team of Caltech graduate students are developing the "excutive programme" or operation system of the robot. It is the programme through which scientists and engineers back on Earth would communicate with it.

The "breadboard" robot is presently being assembled. Completed subassemblies are already housed in a converted helicopter hanger at JPL. By January 1975 the research teams plan to have the TV cameras, laser and 5 ft.-long manipulator operational and mounted on a flat table. At that time the robot should be able to pick up a rock, display it to the cameras and deposit it on the table. By July of next year the robot's parts will be placed on a flat-bed vehicle about the size of a Volkswagon, enabling the whole to move about.

Successors of this first robot won't be ready for a trip to Mars until 1985 or 1986. After the artificial intelligence has

been developed for the present hardware, much smaller, more compact versions must be designed and built into a compact, lighter-weight unit. One assumption of the programme is that in this 1985 era, technology will permit extreme miniaturization of computers so that a so-called "large" computer of today will fit on an operational robot.

Computer programmes are being written now to co-ordinate the visual system and the manipulator. The present manipulator has seven joints for which large planning and control programmes must be written. Eventually the robot may have a second arm with a vice-like "hand".

The redundant visual systems have advantages, Whitney explained. TV eyes can be confused by shadows; laser range-finders do not suffer from this deficiency. On the other hand, TV can get texture and colour which the laser cannot provide.

Some activities will be done without human support and some with it, Weinstein said. More advanced actions will require directions from humans. Local and simple activity will be controlled by a minicomputer, which will be supervised by a software system using the existing PDP-10 computer at Caltech.

When an operational flight mission system is designed, large computers will be located in several places – one or more systems on Earth to assist the ground operations, possibly one in orbit around a planet that the robot is investigating, or alternatively, one on the surface of that planet near the robot.

The JPL approach toward developing a rover is different from that of the Russian Lunik rover on the Moon. While the Russian machine was of the master-slave type, which is completely under the remote control of humans, the JPL rover is designed to have an increasingly growing autonomy. This means it can be made gradually more self-reliant, and some day, perhaps, would be able to do very complex tasks on its own.

The master-slave arrangement is not satisfactory for exploring a planet that is some distance from the Earth, Weinstein pointed out. If the planet is more than a few light minutes away (the Moon is about three light seconds away in round-trip time), then the master-slave control system becomes unsatisfactory, and the robot must control its own activity and have some ability to make decisions on its own.

"The distance to Mars is large and makes necessary a robot with artificial intelligence", Weinstein said. "The minimum time for a radio message to reach Mars from Earth is six minutes – a 12-minute round trip. It can be up to half an hour for a round trip message from Earth to Mars. For that length of time the robot must have some autonomy to survive and to be effective. In fact, ideally, the human is removed from the details of robot control, serving the capacity of an adviser to the robot when necessary".

Most of the computer programmes of the robot are so complex that they require a very large computer system for their development and operation. As an example of the amount of information required for certain operations, Weinstein noted that every Mariner-type television picture contains over a million bits of information. To pick up a rock, a Mars robot might have to analyse many such pictures.

"In our initial design, the robot will have a limited autonomy restricted both by the state of the art of artificial intelligence and by the size of the computer system available. But it is conceivable that in the not far future a very large computer system could be compressed into the size of today's minicomputer, and that the only limitation for an advanced, autonomous robot is our ability to provide the necessary software, a limitation that might be with us for some time.

"For this reason we selected a strategy that might fit both the fast development of complex hardware and the slow development in software. For the former we have selected very large computer systems. For the latter we are working on a design of a variably autonomous robot, i.e. a machine that will provide an easy switch from complete dependence on support by man to a growing autonomy".

LASER LIGHT FROM NUCLEAR SOURCE

Fission energy from a nuclear reactor has been converted directly into laser light for the first time in experiments sponsored by the National Aeronautics and Space Administration. These experiments could lead to major advances in energy conversion, long range communications, and power transmission over large distances.

Experiments were successfully conducted at the Atomic Energy Commission's (AEC) Los Alamos Scientific Laboratory, New Mexico, by Drs. T. F. Wimett and H. H. Helmick of this laboratory, and Prof. R. T. Schneider of the University of Florida, Gainesville.

For these experiments, the Los Alamos Godiva reactor provided the pulse of neutrons to produce energetic fission fragments for exciting a laser gas consisting of helium and xenon.

According to Dr. Karlheinz Thom, who initiated and participated in this work, these experiments prove the feasibility of laser light production by fission fragment excitation, i.e. directly from nuclear energy. Dr. Thom is Plasma Physics Programme Manager at NASA Headquarters, Washington, D.C.

While these experiments used a Godiva reactor, a full scale nuclear-pumped laser would most likely depend on a gaseous-fuel nuclear reactor as a source of energy. Gaseous-fuel reactors have been studied in the past in research programmes managed under the joint NASA-AEC Space Nuclear Systems Office.

Research on gaseous-fuel reactors continues under NASA sponsorship at Los Alamos and the NASA Langley Research Center, Hampton, Virginia, to seek breakthroughs in space power and propulsion for which these recent nuclear-pumped laser experiments may have major benefits. In addition, conversion of nuclear energy into laser light as well as gaseous-fuel reactor concepts themselves could have a major impact on terrestrial uses for nuclear energy such as converting water to hydrogen fuel and producing useful compounds by photochemical processes.

MILITARY WEATHER SATELLITE

An automated satellite to maintain a weather watch around the world for the U.S. armed services is being developed for the U.S. Air Force by RCA Corporation. The versatile new spacecraft system is designed to handle everything automatically, from steering the booster to the accurate positioning of the satellite and its sensors in orbit. Called the Block 5D Integrated Spacecraft System, it incorporates a unique "two-in-one" design approach in which the space-

craft provides both critical launch and in-orbit functions in one highly automated integrated unit.

The Block 5D spacecraft, which is considered a major breakthrough in spacecraft design and performance, is being developed by RCA Astro-Electronics of Princeton, New Jersey, under contract to the Air Force Space and Missile Systems Organisation (SAMSO). The contract calls for the design, construction and testing of three spacecraft systems and the provision of launch services.

Explaining the project Mr. J. R. Staniszewski, Programme Manager of RCA Astro-Electronics, said: "Because the launch vehicle and the satellite share the use of many of the same sub-systems, the overall weight, cost, size and complexity of the spacecraft/booster combination is significantly reduced. Among dual functions provided by the spacecraft are data processing, inertial position measurement, communications, telemetry and power for both launch and on-orbit phases of the mission. The system, the largest and most advanced in the Air Force's weather satellite series, will provide expanded global coverage as part of the Defense Meteorological Satellite Program (DMSP).

The satellite, more than double the size of current operational military weather sentinels, will carry a wide range of sensors and instruments.

"This system inaugurates a new generation of operational systems designed to supply the most timely, high-quality meteorological data possible within the state-of-the-art today", said Mr. Staniszewski. Heart of the Integrated Spacecraft System are two compact, seven-pound processors, capable of operating at speeds of 90,000 instructions per second using only 4.5 watts of power. The processors provide ascent phase guidance for the launch vehicle from lift-off through orbit insertion and also perform the complex tasks associated with primary and back-up orbital attitude determination and solar array orientation control for the satellite.

With the use of the processors, the guidance system becomes completely automatic, eliminating any requirement for command signals from the ground to perform its functions. The attitude control system is also automatic, assuring extremely high pointing accuracy for accurate positioning of the sensors.

This has greatly improved the task of accurately correlating the spacecraft attitude and location with the collected data.

At launch, the Integrated Spacecraft System including the heat shield, weighs 6,000 lb. and stands 24 ft. tall. When in orbit, after depletion of solid expendables and the separation of the second stage solid propellent motor, the spacecraft mass is about 1,000 lb.

It measures 17 ft. with the solar panels deployed and is approximately 5 ft. in diameter. Eight 2 x 6 ft. solar panels can produce up to 850 watts by converting solar energy into electrical power. The spacecraft will be launched into a Sun synchronous polar orbit approximately 450 nautical miles above the Earth.

Mr. Staniszewski said the system is responsive to military operational requirements. "On board the satellite", Mr. Staniszewski said, "is a highly advanced meteorological payload, including scanning radiometers to sense high resolution imagery of cloud tops and sounding instruments to measure temperature and water vapour distribution in the Earth's atmosphere". The sensors, capable of operating at any local Sun time, will obtain data primarily at sunrise, noon, during the early evening and at midnight.

The Block 5D satellite will view every portion of the Earth at least twice daily, taking high resolution pictures of clouds as small as 1/3 mile across, in both visible and infrared spectral regions.

"Previous RCA-built satellites flown by the Air Force have already demonstrated their unique observational capabilities. [These spacecraft, which have an orbiting mass of less than 500 lb., resemble truncated cones]. Dramatic nighttime pictures showing the lights of major cities have been obtained, along with infrared photos of the Aurora Borealis. The scanning radiometers also take pictures of jet streams and storm systems that are vital for weather analysis and forecasting, "Mr. Staniszewski added.

The temperature sounders measure the vertical temperature distribution of the atmosphere on a global basis from sea level to above the cloud tops in clear areas. Water vapour is also measured to obtain moisture profiles in the atmosphere throughout the entire world.

"Collected by satellite and beamed back to Earth, this valuable data will be used by the Air Force and other weather centers for numerical weather analysis and to support vital research and investigation of the global atmosphere", he said. Together with high resolution imagery, the temperature and moisture readings of the atmosphere are recorded for transmission to either of two Air Force command and control and data acquisition sites located at Fairchild Air Force Base, Washington, and Loring Air Force Base, Me.

Simultaneously the information will be relayed to the Air Force Global Weather Central, Offutt Air Force Base, Nebraska, for analysis, data processing, and distribution to Air Force bases throughout the world.

Views of local area weather conditions can be transmitted in real time by the satellite directly to field unit commanders for their tactical use through a system of air transportable vans. The vans, which can be flown anywhere in the world and set up within a matter of a few hours, are equipped to receive both visible and infrared imagery directly from the satellite. A direct readout terminal also has been installed on the U.S. Navy's aircraft carrier, the *USS Constellation*, to enable it to acquire weather information from the satellite.

TRACKING HURRICANE CARMEN

The national space agency played a double role in both tracking Hurricane Carmen and housing storm refugees at one of its centers last September as Carmen lashed the Gulf Coast.

NASA's newest weather satellite, Synchronous Meteorological Satellite 1 (SMS-1), for the first time permitted a 24-hr., day and night watch of the storm by the National Oceanic and Atmospheric Administration's (NOAA) National Hurricane Center in Miami, Florida. And at NASA's National Space Technology Laboratories near Bay St. Louis, more than 7,000 storm refugees from Mississippi Gulf Coast communities and from low lying areas in nearby Louisiana, were housed and fed.

The refugees began arriving at the Center early on 7 September when the Gulf Coast was put on hurricane warning and they remained at the NASA installation until the next day when Carmen went inland on the Louisiana Coast and began to break up and lose punch in its slow journey through the state. Also taking refuge at NSTL and advantage of the

Center's unique harbour and canal systems were 13 Navy vessels from New Orleans as well as 75 small craft – shrimp, fishing and pleasure boats – from the Gulf Coast.

Dr. Neil L. Frank, director of NOAA's Hurricane Center, reported: "The cornerstone for our operations at the Hurricane Center is weather satellite coverage". With the help of SMS-1, he said: "We had a smaller margin of error for Carmen than for any hurricane in a very long time. The warnings worked exceptionally well and we were very lucky in the small loss of life and property.

"The impact of the day-night SMS-1 time-lapse pictures has been most dramatic in helping our understanding not only of hurricanes and tropical storms but of the total weather pattern in the Atlantic".

The 627-kg (1,400 lb.) SMS-1 spacecraft transmits electronic data to produce day and night pictures of the Western Hemisphere every 30 minutes from its station about 36,000 km (22,300 miles) over the Equator just off the east coast of South America (*Spaceflight*, October 1974, pp. 383-387).

The refugee operation at NSTL involved emergency teams of some 175 NASA and contractor employees with American Red Cross workers and volunteers from other agencies located at NSTL with local community support. Nineteen buildings – offices, laboratories and even test towers – at NSTL were used as public shelters and the Red Cross provided 19,000 meals for the refugees.

During the alert, the emergency teams remained in constant radio contact with Civil Defense groups and other governmental agencies in the area, and were ready to assist local communities if the hurricane struck.

NSTL recently became a permanent NASA field installation, reporting directly to NASA Headquarters. It is the site where NASA and several federal and state agencies conduct remote sensing, environmental and related research and technical activities.

HURRICANE WARNINGS FROM SPACE

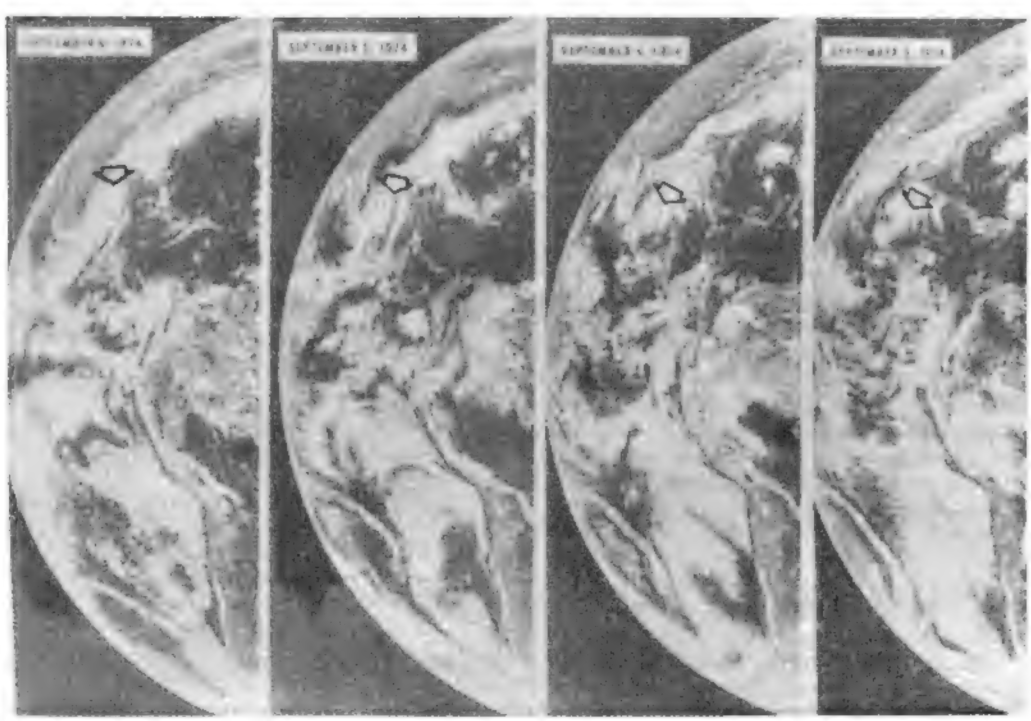
The vital importance of artificial satellites for providing advance warning of hurricanes has been emphasised by Dr. Neil L. Frank, Director of the National Oceanic and Atmospheric Administration's Hurricane Center in Miami, Florida. The Center's weather-detecting ability recently was augmented by NASA's new Synchronous Meteorological Satellite-1 (SMS-1), launched on 17 May 1974, which is used in conjunction with the older Applications Technology Satellite-3 (ATS-3), and with polar-orbiting NOAA and Nimbus satellites.

Today "there is no way a major hurricane or severe storm can strike the United States undetected", Dr. Frank said. Satellites such as the SMS and the ATS, in synchronous orbit at an altitude of 22,300 miles (36,000 km), scan the whole Western Hemisphere every 30 minutes for NOAA's National Weather Service and National Environmental Satellite Service (NESS). They can pick up disturbances that represent a threat to the eastern United States as they form off the coast of Africa to move across the Atlantic Ocean.

That area seems to be the breeding ground for about half of the approximately 100 storms that may build in intensity to the status of tropical storms or hurricanes. Others fated to become severe storms originate in ocean regions closer to the Americas.

Satellites are extremely important because they provide early warnings and data to measure speed and the circulation of winds. Many hurricane seedlings are born over Africa's Sahara Desert and become tropical storms when the hot Sahara air meets the cool air along the coast of Africa.

Frank says the "dramatic impact of geosynchronous orbit satellites was apparent with the launch of ATS-3 in 1967, which showed us, for instance, that there were about twice as many tropical storms forming off the west coast of



NASA's Synchronous Meteorological Satellite (SMS-1) tracks hurricane Carmen (arrowed) northward from Mexico's Yucatan Peninsula towards the U.S. Gulf Coast in this series of pictures taken at the same time each day. The satellite, located in geo-stationary orbit over the equator off the east coast of South America, provides continuous coverage of much of the Western Hemisphere, returning full-disc pictures of Earth and data for selected closeups. The impact of the day-night SMS-1 time-lapse pictures has been dramatic in helping our understanding not only hurricanes and tropical storms but of the total weather pattern in the Atlantic, says Dr. Neil L. Frank, director of the National Oceanic and Atmospheric Administration's Hurricane Center in Miami.

National Aeronautics and Space Administration

Mexico as we had thought. "Before 1966, we had spotted an average of only seven or eight potentially severe storms per year forming in the area, but after ATS-3 was up we saw an average of about 15 each year, west of Mexico".

Satellites obviously are not the only method used to spot and track hurricanes and tropical storms. The Hurricane Center has 250 miles (400 km) range radar and military aircraft on call to fly into the storms for precise measurements and computerized predictions of storm-surge heights expected from rapid water rise and high waves. Estimates show that nine of ten hurricane deaths are from drowning. These occur because of the rapidity with which water rises to dangerous heights.

Adjacent to the Hurricane Center office is NOAA's NESS Satellite Field Services Station (SFSS) which receives satellite-observed sea-surface temperature readings from around the world to feed into the Hurricane Center's computer. NOAA and NASA satellites such as those in the Nimbus and NOAA series measure vertical temperatures over the oceans, which give sea-surface and upper-air temperatures over the oceans at about 30 mile intervals.

The NESS SFSS staff keeps a careful eye on these readings to detect ocean heating or the development of a hot spot that could cause the air to rise and speed up air motion. In effect, the atmosphere "boils". The column of hot air bubbles up, the cold air spills down (much like water), and the continuous motion provides energy. Over a wide enough area, that portion of the atmosphere begins rotating and becomes a storm whose air motion can be seen and tracked *via* satellite. Thunderstorms, which can pack the energy of hydrogen bombs, may even look like the mushrooming clouds of H-bomb explosions on a series of satellite pictures.

Donald C. Gaby, SFSS manager, says his organisation has a new tool, in SMS-1: "It's the first time we are able to see the whole hemisphere continuously day and night and in infrared". This day-night-infrared capability allows SFSS operational meteorologists to make analyses of cloud heights and movement and infer wind speeds. NOAA polar orbiting satellites see such things as eddies in the Gulf Stream, even spot the demarcation point of cold and warm water.

All this information, including reports from ships and meteorologists in other countries, is analysed and then relayed to weather centres along the Gulf Coast, Florida, and the East Coast for localised forecasts. At the same time the Hurricane Center provides similar information on request to Central American and Caribbean areas.

The part played by governmental weather trackers responsible for providing information on the progress of potential killer storms to residents of the United States, Caribbean Islands, the Bahamas Islands, and Central American countries was well illustrated recently when Hurricane Carmen swept through the Atlantic Ocean. Satellites, reconnaissance aircraft, radar stations, and land-based scientists tracked the dangerous storm from the African coast beginning 23 August 1974, to its Gulf of Mexico point of entry into the United States on 8 September.

WEATHER SATELLITE TV REPORTS

Last September NASA undertook a 30-day weather satellite picture experiment with the American Broadcasting Company, Columbia Broadcasting System, National Broadcasting Company and United Press Independent Television News. The Goddard Space Flight Center provided on a daily basis tape recorded time-lapse cloud pictures obtained from the Synchronous Meteorological Satellite-1 (SMS-1) showing the weather in motion for a 72-hour period. The satellite, in geosynchronous orbit just north of the mouth of the Amazon River, Brazil, maintains continuous day-and-night coverage of much of the Western Hemisphere.

The pictures, in both false colour and black-and-white, covered the weather situation for 72 hours up to 11:00 a.m. of the day they were delivered at 4:00 p.m. The television networks thus were able to transmit the photographs to affiliated stations in time for the evening news reports.

The series of pictures on the tapes, for example, could trace the movement of a hurricane across the Atlantic Ocean during a 72-hour period and show where it was on the day the tapes were distributed.

From its vantage point, the spacecraft could see most of the Western Hemisphere, North and South Atlantic oceans, and the west coast of Africa. This is an especially favourable location for hurricane watching because most hurricanes are born off the coast of Africa and move westward towards the United States.

Early this year, another SMS will be placed in orbit, to occupy SMS-1's present position. SMS-1 then will be moved to a position over the Galapagos Islands off the west coast of South America, where it will have an excellent view of the entire United States.

NASA's newest weather satellite, SMS-1 can take pictures of the area viewed by its telescope every 30 minutes. It is the first synchronous satellite to have a day-and-night picture taking capability. Its infrared imaging system returns pictures with five-mile resolution and its visible-light system provides ½-mile resolution.

NASA supplied the infrared camera images to the four television news companies to enable them to maintain day-night continuity.

SPACE AID FOR EVERGLADES

Satellite technology is helping to preserve Florida's Everglades National Park through environmental assessments made possible by teamwork between the U.S. Geological Survey and NASA's Goddard Space Flight Center.

Under the direction of Aaron L. Higer, of the USGS in Miami, the ecological balance of the 3,600-square-kilometer 1,440 mile^2 (3,600 km^2) area is constantly surveyed by 20 small data collection platforms (DCPs) situated strategically for water resource management. The DCPs radio their readings to NASA's Earth Resources Technology Satellite (ERTS-1) when it passes overhead, and the satellite relays the reports to a ground station.

The information is important not only to the animals and vegetation of the Everglades, but to the 2.5 million human inhabitants of southeast Florida, including those in densely populated Miami.

Until the platforms were emplaced it was difficult to get accurate readings of the amount of water in surface storage because of the large area involved, the shallow water depths, the flat terrain, and the large amount of vegetation. Except for a few radio microwave reports, all readings were made as a result of personal visits to individual stations in the Everglades about once a month. The analysed data reached users

about two months after initial recording.

Now that the DCP network is operational, users can have data from the most inaccessible regions in the Everglades – even from the middle of Lake Okeechobee at the top of the water-feeding chain to Everglades – usually within 25 to 40 minutes after measurements are taken. In addition, malfunctions in a platform are known immediately and a maintenance man can be dispatched by truck, airboat, or helicopter to make repairs.

The DCP measurements include amount of rainfall, water levels, water flow, evaporation rates, humidity, water and air temperature, salinity, oxygen content, pollutants present, and soil moisture.

"There is probably no limit on the types of measurements we can make with the DCP's", Adron Higer says.

The data obtained are transmitted direct from the DCP to ERTS, which passes within 1,500 miles (2,414 km) on either side if the DCP, at 570 miles (917 km) altitude. ERTS relays the messages to tracking stations located at either Goddard in Greenbelt, Maryland, (where the ERTS Project is managed), or Goldstone, California. From these stations the data are teletyped to the Geological Survey's Miami office, processed through a small computer into suitable format for users, and retransmitted by land line to the U.S. Army Corps of Engineers, Central and Southern Florida Flood Control Districts, the United States Park Service, and the Florida Fish and Wildlife Office.

ERTS imagery also can provide information on the real extent of water surface, but procedures are not yet operational because picture processing is too time consuming. It requires as much as eight weeks for delivery of pictures to users. The imagery has been useful, especially during the 1973-74 winter-spring drought situation, in comparing the surface water area with the range of water levels to calculate the amount of water stored in the various lakes, canals, and conservation areas.

Knowing the surface inflow and outflow makes it possible to calculate the amount of seepage and evaporation and the surface water distribution. Such information on hydrological conditions is important for the management of water resources by state and federal agencies.

Higer says he is now installing sensors on the DCP's that will report when a lack of sufficient soil moisture reaches a point indicating a fire potential. As everglades muck dries in a drought situation, it becomes a peat-like soil easily set afire by human carelessness or even through a form of spontaneous combustion. Monitoring the soil moisture daily will make it possible to prohibit human entrance into danger areas, to pump in additional water, or to increase fire surveillance.

Some 14,000 miles (22,500 km) of canals and levees in the Everglades watershed, as well as numerous dams and pumping stations, regulate the water supply, especially in drought and flood situations. The problem is to keep a good balance by allocating water from lakes such as Okeechobee (north of the Everglades) to farmers for irrigation purposes; keeping a sufficient flow of canal water for animals, fish, and vegetation; preventing salt water intrusion; and making certain there is sufficient water to recharge the underground water supply from which the city of Miami draws fresh water.

"This ERTS data-relay system has been very reliable", says Higer, "and by coupling the ground information with ERTS imagery, a modeling technique is available for water resource management in southern Florida".

SPACE MANAGEMENT OF WATER

NASA's Earth Resources Technology Satellite (ERTS-1) is rapidly becoming an important tool for hydrologists as more and more data are returned from the spacecraft and analyzed in relation to present water resource management practices which permit man to extract water economically from only about 0.01 per cent of the total global supply.

In industrial nations it is apparent that better utilization of water is necessary. The United States per person demand in the larger cities, for example, is more than 20 times that required by a person living in some of the under-developed countries.

Another example: Annual flood losses in the United States can exceed $1,500 million a year, and with further land development on flood plains this cost will continue to rise. On the other hand, many major cities are threatened with short water supplies and need new sources.

ERTS data can help in the management of these and other problems by observing and monitoring large areas on a repetitive basis to provide indices of the volume of water available in a particular region. For example, satellite observations of surface water and snow accumulation, or even possible location of subsurface water supplies in relation to urban centres, irrigated areas, and industrial development, make future planning more accurate, economical and coordinated.

ERTS data are being used for flood control, irrigation, and soil moisture identification; ground water level measurements; lake and dam counts; identification of current circulation patterns; pollution and sedimentation in estuaries and lakes; ice and snow coverage; even glacier and iceberg monitoring.

Images of surface characteristics are used as well as information from small Data Collection Platforms (DCP's), which collect surface data and transmit them to orbiting satellites for retransmission to water resources management agencies, often in less than one hour. DCP's gather information impossible or difficult to acquire by other means.

More than 100 DCP's are now operating from Iceland to Hawaii and Northern Canada to Central America. There will be more later to work not only with ERTS-1, but with Nimbus, the new Synchronous Meteorological Satellite, the later Geo-Stationary Operational Environmental Satellite (GOES) to be operated by the National Oceanic and Atmospheric Administration (NOAA), and follow-on advanced Earth Resources Environmental Satellites.

Dr. Vincent V. Salomonson of NASA's Goddard Space Flight Center, which manages the ERTS project, notes in a recent paper on advances in water resource monitoring from space, that as more sophisticated spacecraft are phased into use by hydrologists, the jobs of processing, analysing, and getting the data to the user on a timely basis will have to keep pace with satellite development.

Dr. Salomonson and other scientists of NASA and other government agencies, such as the U.S. Geological Survey (USGS) in the Department of Interior, list many examples of advances in water resource monitoring by satellite. They include:

(a) Liquid water appearing in the form of clouds was one of the first characteristics measured by meteorological satellites. Rainfall is now measured over remote ocean areas with instrumentation on the newer Nimbus satellites. Even water vapour in cloud free areas can be

measured to provide better information on relative humidity distribution and the global water balance.

(b) Synchronous satellites can observe the severe storms which provide heavy precipitation that is the basic input to water-shed systems resulting in runoff and occasionally hazardous or damaging floods. They can provide better understanding of convective clouds, usually associated with thunderstorms or tornadoes, and significant cloudtop features such as bubbles, often seen on the top of the typical anvil clouds associated with severe storms or tornadoes. Even cloud top temperatures as well as vertical temperature measurements down to the surface are obtained from satellites circling the globe in polar orbits. This information is especially useful in severe weather forecasts.

(c) The first high-resolution, synoptic look at an entire flood area, the Mississippi River Basin during the 1973 floods, came from ERTS-1. It provided imagery for measuring flooded acreage and evaluating flood control structures as well as much other useful data.

(d) Drainage patterns and snow-covered areas are easily seen on imagery from ERTS, Nimbus, and the NOAA satellites. The change with time in the amount of snow-covered area and the elevation and location of snow lines can be accurately observed. Snowline altitudes in western mountains can be located to within 180 ft. (60 metres) using ERTS imagery. Because a large portion of water in the west comes from snowmelt, its accurate prediction is very important in water management and in resulting monetary benefits.

Reproduction of a colour composite photograph of the Buffalo/Niagara Falls/Toronto area from the Earth Resources Technology Satellite-1 (ERTS-1) taken from an altitude of 568 miles (914 km). Healthy crops, trees, and other green plants which are very bright in the infra-red but invisible to the naked eye, are shown as bright red. Suburban areas with sparse vegetation appear as light pink and barren lands as light grey. Cities and industrial areas show as green or dark grey and clear water is completely black. Some of the notable geographical landmarks are: Lake Ontario (centre right); Toronto, (centre); Buffalo (lower right); Hamilton, (lower right between Lake Ontario and Lake Erie); Welland Canal (to left of Niagara); Niagara Falls (midway between lakes of Niagara River above Grand Island); Georgian Bay (extreme upper left corner).

(e) Infrared observations are being used to monitor, repetitively, the number and area covered by thousands of small and shallow lakes in the southwest, a task that was impractical before the launch of ERTS-1.

(f) The U.S. Army Corps of Engineering uses ERTS data for locating, identifying by size and shape, and counting bodies of water as small as approximately two hectares (six acres). The spacecraft is also used to help locate sites for dams on major rivers.

(g) USGS scientists have found it is possible to infer the presence of ground water supplies beneath the surface from ERTS-observed geologic features, and there are some indications that soil moisture content to significant depths below the surface can be obtained using satellite electromagnetic radiation sensors which interact directly with water. Also, faults or linear features may reflect such subsurface structures as limestone deposits, where ground water may exist. An example is the successful drilling of a shallow water well near Flagstaff, Arizona, located on the basis of information obtained from ERTS-1. Other wells are expected to be drilled in the same area by the City of Flagstaff.

(h) Circulation and sedimentation patterns observed by ERTS are being used by the State of Delaware to develop a deployment strategy for oil-spill control equipment and by the State of California to estimate the amount of sand transported along the coast.

(i) New water bodies such as Lake Anna Reservoir in Virginia, and coastline changes in the U.S. or other countries can be spotted immediately by ERTS and up-to-date photo maps produced.

(j) Turbidity variations caused by suspended sediments, organic pollutants, or algae material, which cause relative differences in the colour or reflectance of the water, can be observed in ERTS pictures.

(k) Water volume measurements are being made by the USGS and Corps of Engineers in Florida combining ERTS imagery and DCP information to calculate not only how much water is present in previously unmeasureable places such as swampy regions, but also to assist in deciding whether to release water from one storage area to another.

(l) Wetlands can be acurately monitored and mapped for inland states such as Wisconsin; land-water interface, upper wetland boundaries, and gross vegetation can be defined in coastal regions; and even information on drainage patterns, ditching activities, and lagooning for waterside homes can be observed in detail.

(m) Glacier ice has been monitored by the USGS from

New York is seen in this ERTS-1 photograph. Long Island and Long Island Sound are seen at upper right; Hudson River and New York City at upper left, and the New Jersey coast including Sandy Hook, left of centre. The sandy beaches along the Long Island and New Jersey Coasts stand out clearly. Rows of small fair cumulus clouds cover Brooklyn, Queens, the lower part of Manhattan, North Jersey and Westchester County. The light grey shades over New York City and the harbour indicate the haze and smog of this metropolitan area. Central Park with its lake can be seen in upper Manhattan. Contrasts between the marshlands and pine forests in southern New Jersey and the suburban areas further north are clearly evident.

National Aeronautics and Space Administration

spacecraft pictures (nearly 80 per cent of the world's fresh water is contained in glaciers and icecaps) for purposes of identification, location, and movement. By studying glacier moraines (areas of trapped dirt and debris) and the movement of snow lines on glaciers, it is possible to infer the mass balance of these chunks of ice left over from the time they covered vast portions of the U.S., Europe, and Asia.

Surging glaciers (those that may move abruptly several kilometres) can be distinguished from non-surging glaciers. Surging glaciers may advance over large areas, causing devastating floods by blocking and suddenly releasing large quantities of melt-water. An 1,980-yard (1800-metre) surge was observed by ERTS in 1972 in Alaska. In 1973 evidence was seen of another surge that dammed off a river in Soviet Asia, forming a lake of some 20 million cubic feet of water before bursting the ice dam.

Knowledge of location and movement of sea ice and icebergs is of considerable interest to the shipping industry. ERTS has demonstrated that it can be used to identify ice types, distribution, and movement and to provide information on rate and location of ice break-up.

SHIP-TO-SHORE COMSAT TEST

NASA and the Maritime Administration have successfully demonstrated the feasibility of using a satellite for high quality ship-to-shore communications on the L-Band frequencies (1.5 to 1.7 GHz). Future operational systems of this type for both maritime and aeronautical application could save millions of dollars by speeding up day-to-day operations.

Certain frequencies in the L-Band range were allocated for operational maritime and aeronautical communications *via* satellite by the United Nation's World Administration Radio Conference in 1971. Tests conducted recently with NASA's Applications Technology Satellite-6 (ATS-6), a communications research and development spacecraft, provided high quality duplex voice link data and experience.

The test transmissions originated at the National Maritime Research Center in Kings Point, New York, and were relayed by the ATS-6 to the *American Ace*, a commercial container ship. At the time, the ship was *en route* from Norfolk, Virginia, to Le Havre, France.

All shore and shipboard equipment employed was designed for operational use. Control of the ATS-6 for the tests was maintained at NASA's Goddard Space Flight Center, Greenbelt, Maryland, where the spacecraft project is managed for NASA.

Only one of 20 experiments on the versatile ATS-6, the L-Band experiment is designed to demonstrate and evaluate applications of a geosynchronous orbit spacecraft for maritime and aeronautical communications and position location.

Information from the current phase of the L-Band tests will be of particular value to the Maritime Administration, which is anxious to evaluate the economic benefits associated with spacecraft communications technology. Potential benefits include the transmittal of cargo manifests and documentation prior to ship arrival in port, transmittal of payroll data for shore processing, and the remote monitoring and transmittal of ship machinery performance.

Further tests are being conducted with the ATS-6 L-Band experiment to evaluate several communications and position location techniques, using the ATS-6 as well as NASA's ATS-5 spacecraft, in conjunction with aircraft and ships.

Position location tests require altimeter readings from aircraft and accurate range measurements of the distance from three ground stations to each of the two ATS spacecraft.

From its position at 94° west longitude over the equator, a point above the Galapagos Islands, the ATS-6 will provide two-way communications between ground stations and mobile units operating in a 672 mile (1,081 km) wide area extending from the U.S. east coast two thirds of the way across the mid-Atlantic Ocean.

In addition to NASA's Goddard Space Flight Center and the Department of Commerce's Maritime Administration, other active participants in the L-Band experiment include the U.S. Coast Guard and the Federal Aviation Agency of the Department of Transportation. The experiment also is international in scope, with participation by Canada's Department of Communications and Ministry of Transport, and the European Space Research Organization.

X-RAY DATA HANDLING

A £27,000 contract to study the data handling system for EXOSAT – the European Space Agency's latest X-ray scientific satellite project – has been awarded to British Aircraft Corporation's Electronic and Space Systems Group. EXOSAT, to be launched in 1979 is designed to probe X-ray sources in outer space determining their position, size and shape, energy spectrum, and how they vary with time.

Under the 6-month contract BAC will consider whether EXOSAT should have an on-board computer to control its attitude in space, compute data from the X-ray experiments and provide a 'quick look' facility for experimenters. Alternatively, these essential tasks could be largely controlled from Earth using purpose-built electronics on-board the satellite to assist the ground based system. It is possible that an on-board computer could provide significant advantages in reducing the satellite's weight and power consumption and in improving mission flexibility and hence EXOSAT's scientific value. In addition, the 'quick look' facility that a computer could provide would give experimenters important up to the minute data about the satellite's behaviour and location and preliminary scientific data to allow decisions to be made concerning the satellite's mission strategy.

Dornier System are assisting BAC in the study of the experimental payload data handling requirements. The competitive industrial project definition phase for the EXOSAT programme begins in 1975.

MYSTERY GAMMA BURSTS

More information on the high-energy gamma radiation bursts picked up by Russian and American satellites (*Spaceflight* September 1974, p. 334) has been forthcoming from Andrews Air Force Base, Maryland, and other centres. Scientists at the Los Alamos Scientific Laboratory in New Mexico say they have recorded more than 20 of the puzzling outbursts over the past four years. They believe that the U.S. Air Force Vela satellites have discovered a new class of astronomical objects in deep space.

The Vela programme, a joint Department of Defence and Atomic Energy Commission project, is designed primarily to detect nuclear explosions in space. The Air Force Systems Command Space and Missile Systems Organization (SAMSO) manages the development programme and another SAMSO unit, the Air Force Satellite Control Facility, provides in-orbit monitoring and data collection.

Astronomers and astrophysicists view the new astronomical objects with an interest akin to the discovery of pulsars and quasars. No name has been given to the new objects.

The four Vela satellites which detected these new radiation bursts are distributed around a common orbit. The short, well-defined bursts of gamma rays are timed as they arrive, in turn, at the various satellites. The direction of origin is then computed from the time differences.

Positive source directions have been confirmed for nine of the twenty events. Satellite data from twelve independent groups have now confirmed one or more of the Vela-detected events.

The locations of these new-found events apparently rule out gamma ray activity within the Solar System, nor do they seem to be of galactic origin. They are estimated to lie between 15 to 500 light-years away or at extra-galactic distances more than a million light-years away.

The kind of source which could produce such energetic bursts of gamma rays is uncertain. Astronomers have examined several possibilities including supernovae, novae, stellar flares, capture of comets by neutron stars, accretion of material onto a white dwarf, neutron star or black hole.

Scientists will continue monitoring Vela's detection systems to gain more information about the cosmic gamma ray bursts.

The discovery was an added bonus of the Vela programme, which has also produced significant real-time data in other areas by monitoring solar flares and other radiation in the solar environment that could affect the safety of man in space. Vela satellites are part of the Air Weather Service's programme for recording and predicting solar events.

MARS CAMERA TESTS

The first tests of the camera that scientist's hope will photograph Mars from ground level when two Viking spacecraft land on the planet in 1976 have been "successful beyond expectations", according to Dr. Thomas A. Mutch, leader of the Viking Lander Imaging Science Team. Dr. Mutch, a professor of geology at Brown University, led a team of 15 scientists, engineers and technicians on two recent field trips to test the camera system under geologic conditions similar to those expected on Mars.

The first test photographs were taken near Denver, Colorado, and another series of pictures was made at the Great Sand Dunes National Monument in southwest Colorado. The team leader was so pleased with the results that he regards the camera's performance and versatility of the system as "unmatched by any that NASA has yet flown on an unmanned mission".

The pictures show remarkable views of several kinds of scenes. Reproduction is extremely accurate, with sharp resolution and excellent detail. Subjects range from panoramic views of a valley near Denver, to the contrasting light and dark of a large rock formation against the sky, to closeups of small rocks and powdered minerals.

Photographs of sand dunes, more than 100 metres high, reveal clearly delineated ripples in foreground and background, patches of dark-coloured sand in the background, and atmospheric haze near the horizon. Stereoscopic views were taken of the same kinds of scenes, revealing excellent three-dimensional perspectives.

The Viking Project, managed at NASA's Langley Research Center, is designed to softly land two spacecraft on Mars after an 11-month journey from Earth. Each Viking spacecraft consists of an Orbiter and a Lander, launched from

Earth in the fall of 1975. The first Lander should touch down on Mars in early July 1976.

The Lander's imaging system consists of two cameras, rising like twin periscopes from the top of the three-legged Lander. They are meant to provide colour, black-and-white, infrared and stereoscopic views of the Martian surface.

Weighing only 16 lb. apiece, the cameras will scan from the nearest Lander footpad to an angle of 40° above the horizon. They will also rotate 340° for panoramic coverage.

The instruments are facsimile cameras, especially designed to operate in unusual conditions, and are fundamentally different from the film and television cameras flown on most other NASA space missions.

Chief distinction of Viking's cameras is that very small photo-diodes (light sensitive devices) are positioned in the focal plane, where film would be in a conventional camera. An image is reflected from a nodding mirror through lenses onto the diode. The mirror rotation essentially scans the image past the diode; each time the mirror moves through one cycle, a single vertical line is scanned in the field of view.

The entire camera is then slightly rotated and the next vertical line is scanned. Because the image information is sequentially acquired, at about five lines a second, several minutes are needed to get a complete photograph.

Colour photos are created by combining data from three diodes (blue-green and red-sensitive), and colours are carefully calibrated and balanced by ground equipment.

Each camera will be an important instrument for most Viking science teams. One of its most important jobs will be characterizing the area near the Lander, so that scientists on Earth can select spots from which samples can be obtained, with a telescoping soil scoop, for chemical and biological analysis in the miniature laboratory aboard each Lander.

The imaging system will also provide photometric information from near-field materials that will help deduce composition and particle sizes; it will monitor the Martian atmosphere's opacity; and record the position of the Sun and brighter planets, permitting precise location of the Lander on Mars.

Because the cameras on both Landers are expected to operate for at least four months, they will also be able to document seasonal changes as they occur.

Viking's Landers will not return from Mars, so photos must be reconstructed on Earth from image signals transmitted through millions of miles of space. Ground equipment reconstructs the photos with a three-beam laser and computer system.

The Lander cameras, which took nearly five years to design and build, are made by Itek Optical Systems of Lexington, Massachussets. Itek is a subcontractor to Martin Marietta Aerospace, Denver, prime contractor to NASA's Langley Center for development of the Viking Landers.

ATS-6 SPACECRAFT CAMERA

The Very High Resolution Radiometer used in one of 20 experiments being conducted with NASA's Applications Technology Satellite-6 (ATS-6) has ceased to produce useable images of Earth. Before its malfunction, the radiometer, an advanced experimental camera-like instrument, had produced more than 1,000 images, which are still being analyzed by project scientists at the Goddard Space Flight Center.

The radiometer thus had achieved its basic assignment of providing data for the evaluation of new concepts in meteorological data collection and analysis for possible use aboard future spacecraft in geosynchronous orbit.

The radiometer malfunction does not affect the main activity of ATS-6, which is the transmission of educational and health television programmes to small, inexpensive ground receivers in isolated communities. These transmissions and all other ATS-6 experiments are continuing.

SPACE SPOTLIGHT

More than five years ago, NASA initiated a programme for the design of engineering models of a concentric electrode arc needed in spacecraft environmental test chambers. Basic technology was amassed, and out of this now has come a product which is expected to be particularly useful to police and fire departments and to the general public, especially in emergency situations.

It is a portable, battery-powered spot-light, the brightest hand-held light of its type ever produced, with an intense, true colour beam roughly 50 times brighter than the high-beam headlights of a car.

Called the Stream Lite-1 Million, it weighs 7 lb. (3 kg) and uses a unique xenon–xenon is a heavy, colourless, inert gaseous element – lamp with an operating lifetime of at least 200 hours at maximum intensity.

The Stream Lite-1 Million can operate in a steady or pulsed light mode. Its intense beam is especially useful in penetrating fog and smoke, as it gives off less return light "back scatter". It operates on a standard 12-volt direct current rechargeable portable battery pack or from the cigarette lighter receptacle of a car. Manufactured by Streamlight, Inc., Fairfield, NJ, it retails for about $400.

JBIS SPECIAL ISSUE

The special issue of *JBIS* devoted to **Maritime Satellites** appeared in October. It contained the following main features:

Captain B.H.G.M. Baynham	What The Shipowner Needs
G.H.M. Gleadle	Maritime Satellites – A Survey
J.A. Vandenkerckhove	The ESRO MAROTS Programme
J.D. Parker	Maritime Mobile Satellite Communications: The Ship Terminal
M. Bertrand	Low-Cost Shipborne Antenna System for Satellite Communications
T.M.B. Wright	The U.S. Navy Marisat System as a Basis for Global Navigation
D.L. Brown, G. Melchoir and F. Absolonne	Results of a Maritime Satellite Simulation Experiment
P.J. Conchie	The Adoption of OTS to the MAROTS Role

Copies are obtainable by members at the specially reduced rate of 55p ($1.50) post free.

ALADDIN '74

A personal account of an unusual series of sounding rocket experiments in America.

By A. D. Farmer*

'Spaceflight' often publishes personal accounts of the historic happenings of space exploration. Yet alongside the Apollos, Skylabs, Mariners and Pioneers, is a vast network of research and development upon which they are based, and without which today's spectaculars would not be possible. Part of the 'backbone' of present space research is the sounding rocket. Many countries too small to participate in the larger space ventures nevertheless run their own national programmes for meteorology, aeronomy, astronomy or Earth-resources studies. The UK has a wide and interesting range of research, while NASA itself maintains a strong programme of launches. The author offers a personal account of, albeit a far from ordinary 'campaign' to place alongside the more widely publicized space spectaculars.

Introduction

Aladdin III was the name given to a series of 54 sounding rocket launches which took place during a period of just over 24 hr. on 29-30 June 1974. The name, coined from the acronym -*A*tmospheric *L*ayering *A*nd *D*ensity *D*istribution of *I*ons and *N*eutrals, explains much of the programme's objectives. It was mainly to further the sciences of aeronomy, meteorology and ionospheric physics. The height range covered, 60-250 km, included the E-region and parts of the D and F – or in aeronomic terms the mesosphere and lower thermosphere (Fig. 1).

With such a large programme encompassing such a short period of time there was only one launching site with sufficient pads and equipment at which to base the operations – NASA Wallops Station in Virginia (now Wallops Flight Center – see Space Report, *Spaceflight*, 16, 8, p. 316). I will not attempt to describe this, since there is a good summary of its geography and work programme in *Spaceflight*, 15, 10, pp. 390-395. Suffice it to say there are six launch areas and for this campaign 24 launchers were used in conjunction with 3 Primary-, 2 Beacon- and 4 Acquisition-Radar sites and several telemetry stations. The range of vehicles utilized included 14 meteorological rockets (Super-Loki) and 16 other small examples of the Viper-Dart/Super-Arcas class. But the main burden for data gathering fell on the 24 vehicles with payloads of greater than 9 in. diameter: Nike-Apaches (Fig. 4), Ute-Tomahawks (Fig. 3) and an Aerobee-170 were among the types used.

A fuller and more detailed description of the vehicles and experiments will be included in a later article to appear in the JBIS; here my intention is to explain how the programme looked through the eyes of one experimenter.

As part of the Upper Atmosphere Group at University College London (UCL) I participated in a team involved with three distinct experiments:

1. We had two electric field probes as piggyback payloads on two Ute-Tomahawks, each with one of the five mass-spectrometers around which much of the programme was built.

2. From two ground stations (originally to have been one) we would attempt to track daytime Lithium cloud releases in the 90-160 km height region, in order to derive winds at these heights.

3. From one station a set of cameras – Hasselblads and a Nikon – would photograph twilight and nighttime Barium and TMA (Tri-Methyl Aluminium) releases, again to derive winds.

Arrival and first Impressions

We arrived in Wallops Island at the end of May. First we were shown the building where the payloads were to be prepared and integrated, and the optical site where the cameras and Lithium-cloud tracker could be installed. The two were a total contrast. The optical site was an observatory dome, building U-40 at Wallops Mainland, with an impressive floor area, a roof which split and rolled back 30-40 metres each side of the building, and expansive accommodation (Fig. 2). Surprisingly, however, the payload preparation area turned out to be a run-down looking hangar behind pad 4, its outside peeling and flaking from the sea spray, its inside choc-a-bloc with stored cable (Fig. 5). With four rockets being prepared inside it looked like a radio spare-parts junk shop.

A meeting on 4 June at the main base canteen was packed with scores of scientists, engineers and ground crew. It is expressive of the scope and size of the Wallops facility that we scarcely again came across most of those present. Project engineers were appointed and the outline plan given in an 'Aladdin Handbook'. Old friends renewed acquaintances. Those on their first 'campaign' sat quietly taking it all in as the others made 'seen-it-all-before' comments and brought each other up to date. The affair was being especially advertised as an 'international' one, with "teams from Canada, Germany and Britain" though I rather wondered if that did not make our team of three sound a little more substantial than we were.

The first week swelled with initial impressions – trying to make some sort of sense of the great contrasts we met. In terms of efficiency this was seen in the way in which the USAF managed to 'lose' our shipped equipment for over a week, yet when 'discovered' had it shipped and delivered in double quick time. Or in the astounding speed (to those of us used to a more 'deliberate' service at home) with which things were done or obtained when we requested them, in contrast to the fiasco with the US Navy described below. Strange contrasts, too, resulted from the recent 'austerity' programme needed after funding cut-backs. Buildings and expensive equipment lay unused for want of money to run them, while the whole, vast Aladdin campaign took place against a backdrop of small economies like putting the experimenters 'on their honour' not to cross the safety barriers when erected, so they would not have to be manned.

All those 'natives' we met were friendly, outgoing, and eager (and quick) to help. Yet I don't think I ever quite got used to seeing Coca-Cola machines on every floor of every building (even government ones); nor the vast scale on which everything was built, with buildings spread out on a scale undreamed of by one from our crowded little isle. It was easy to see why every American family needed at least one car – often two or three – with everything so far apart and an apparent dearth of public transport.

The Virginia coast was pleasant, flat but green – inland fields of maize, beans and potatoes liberally sprinkled with copses of pine and fir, and by the sea, marshy and criss-

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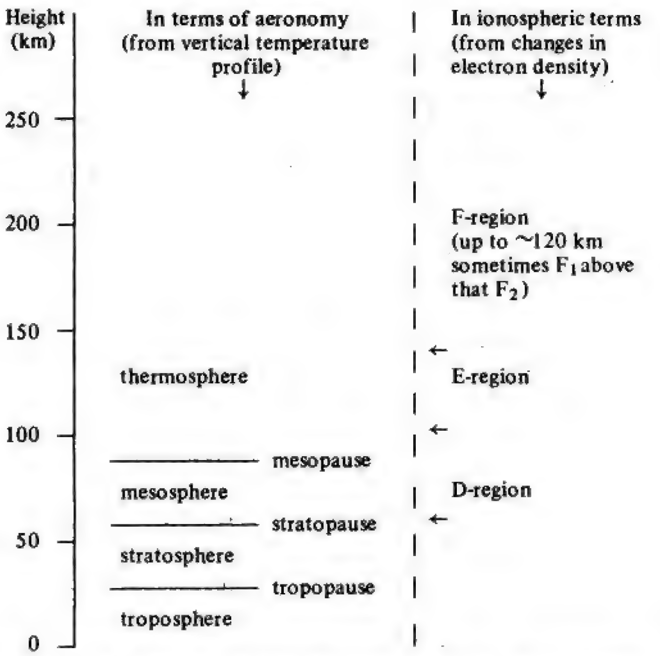


Fig. 1. The 'layers' of the atmosphere aeronomically and ionospherically.

crossed by rivulets. The nearest town, and accommodation, was Chincoteague, on an island at the end of a three-mile causeway over the marsh. Much-beloved of blood-hungry mosquitoes it was nevertheless an interesting, quiet fishing and holiday spot. The nearby beach at Assateague stretched unbroken 30 or 40 miles north to Ocean City, much of it, it seemed, rarely seeing many holiday makers even at peak season.

The Build-Up

The 12-13 June saw the dummy countdown – a full dress rehearsal. Payload engineers and ground crews stayed up through the night. The optical sites were not needed, but those manning them were to discover how useful the exercise had been. Changes were made to the launch procedures in the light of several problems uncovered [such as finding one vehicle did not get 'launched'!].

The rockets had been set up on the pads on the three or four days prior to the dummy countdown, their payloads being wheeled out and mated up last. There they stayed until the launches proper, covered with bags through which a nitrogen purge trickled to keep out sea spray. (The sea is less than 50 metres from the pads with only a beach and dyke separating them).

As the weeks passed the Wallops personnel remained apparently nonchalant about it all. To them, this was just a large spoonful of the familiar mixture as is illustrated by the episode of the test rockets.

The vehicles concerned were small 3 or 4 ft. long met. rockets, usually tube-launched. Several were sent off at odd times preceding the Aladdin fortnight. The only precautions that seemed to be taken was to exclude people from the immediate vicinity with loose chain road blocks, followed by intercom and tannoy warnings – "Test rocket, I cry!" – a few minutes before launch. A one minute countdown ended in a sudden "Whoosh!" as a thick column of yellowish smoke spread itself skyward. No-one bothered getting under cover – one could wander over to the edge of the pad un-molested to watch the rocket go – and for the permanent staff the launches did not offer an interruption to normal routine. I felt like a naive schoolboy just for taking an interest!

In the midst of all this busy preparation, moving apparently like clockwork to its complex conclusion, a rumour of impending trouble began to spread. There was talk that the opening of the launch window on the 17th would have to be delayed. The intention at that time was to have a 12 day 'window', with a good twenty-four hour forecast being needed to send the rockets off in the first five days, and a forecast of a fine night only sufficing for the next five. If the last two days were reached then the rockets would be fired despite the weather, and if this meant the ground sites were covered in cloud then a NASA aircraft would track the chemical releases from 40,000 ft.

The rumour strengthened to a semi-official announcement that the US Navy was 'not allowing' weekday firings. We were told a Russian 'trawler' was lying off the coast, probably waiting to observe Aladdin. The USN felt bound to surround *it.* But this put the number of ships in the impact area at a level above that at which the safety statistics allowed a firing. The 'weekday' clause, so the story went, was because the US Navy was on a five-day week and so would withdraw at weekends, leaving Friday afternoons until Monday mornings free! If that sounds ridiculous to you, imagine the feelings of those hundreds, waiting with millions of pounds worth of equipment, ready at or near Wallops. I cannot vouch that the story was completely true, but it was the only one I heard in explanation of the delays that occurred.

The 17th passed with no action. Then on Tuesday 18th a 'solution' was announced – the campaign would go ahead from Friday 21st until Sunday 30th, with the old 5 + 5 + 2 met. criteria days cut to 4 + 4 + 2. There was relief all round!

The UCL team used the hiatus in activities to set up a second base for another Lithium photometer. This was partly at the request of the Americans, to supply back-up data for their own system, but would also enable us to make our readings totally independent. Each unit could only track the position angle of the Lithium releases with respect to itself as origin. Having two sets of readings would enable a triangulation to be made, to give us the complete spatial solution of position and subsequent movements of the clouds.

The second site used was at Sandbridge, about 90 miles down the coast from Wallops, in the Back Bay nature reserve. Sandbride Beach was the southerly extension of Virginia Beach, which proudly advertised itself as the largest resort city in the world. Ideal perhaps for a holiday, Sandbridge, however, was a bit daunting for would-be experimenters. It felt like the 'middle of nowhere'; 20 miles from the nearest town with any sort of 'centre', the nearest accommodation was 26 miles away in Norfolk. (Virginia Beach being a resort city, though slightly nearer, cost 2-3 times as much!). The nearest cafe was over two miles, the nearest store over five.

The site building had been unused for some time, and although it had a sliding roof that worked (Fig. 7), the front wall that let down as a flap was so rusty it had to be left down (the hole covered by a tarpaulin). There was no drinking water – no water at all for the first few days – and the whole area was beseiged by a type of biting fly during the

daytime, and by mosquitoes after dark. The whole site was at the mercy of the weather.

Like America itself, the weather too, we found, had a tendency to extremes. It alternated from 95° F on two or three days to dismal cold drizzle on others. The warm days often ended in thunderstorms so fierce it turned pitch black at five o'clock, cars could only be driven at a crawl, and many underpasses in nearby Norfolk were flooded. It was little consolation to be told that this was a particularly bad June!

Aladdin Goes

And so to the 'campaign'. As time advanced into the new launch 'window', the weather began to fail. We were left with a week of disappointment and frustration. The picture of steadily falling drizzle that sticks in the mind may not have been true of the whole period, but it fairly sums up one's memory of that time. Friday was nice as holiday weather, but there was too much high cloud for ground observation of the chemical release experiments. After this it worsened. Drizzle and cloud were the order of the day.

At Sandbridge the experimenters would arrive at 8.00 a.m. for the morning weather report, usually to be told the pre-Aladdin shot (a chemical release for ground instrument calibration) was off for that night. They would then hang around for the three o'clock report which usually cancelled Aladdin for the next day. At Wallops the rockets sat on damp launchers, looking morose in their stored, horizontal position. People tinkered with equipment and waited – it was too wet even to go to the beach.

It soon became obvious that the launches were destined for the last two days – Saturday to Sunday lunchtimes. Fortunately the weather seemed to be clearing. Pre-Aladdin was set for Friday evening at 9.10 on this assumption.

Early that day the cloud cover stayed grimly solid. The ground optical sites (U-40, Sandbridge, Coquina which was south of Sandbridge, and Spandau, next to U-40) were each tied in to an intercom net by which they could talk to each other and get met.and status reports from Wallops Control. This was the way news was to reach us over the next couple of days.

The continually optimistic weather forecasts we were receiving, seemed somewhat divorced from reality to those at the ground sites seeing only one gray sheet of cloud from horizon to horizon. The few breaks revealed two more layers yet above that. Then, an hour before zero, as frustration was reaching a peak, it started to clear, almost as if to order. By 9 p.m. the skies at Sandbridge were almost empty and the other stations could be heard giving similar cheerful reports. The groups erupted into action, furiously working to get their instruments working on time. Mirrors had to be turning, telescopes scanning, and camera mechanisms moving film and opening shutters.

At Sandbridge quick repairs had to be made to the UCL equipment when a bolt head stripped at T-20 min. No one experimenter or group is allowed to hold up the shot. If you are not ready it goes without you. This was especially true of the crowded launch routine of Aladdin itself, where success depended on the clockwork precision of staged launches.

As zero was announced for pre-Aladdin a fuse blew on the AFCRL equipment at Sandbridge, unknown to the other experimenters present who were preoccupied with their own tasks. A circuit check, and installation and check of an independent power supply somehow took only four minutes so that miraculously their Lithium photometer was scanning alongside the UCL one when the Nike-Iriquois released a bright orange cloud as it fell through 150 km. Although it was dark for the observers, the cloud was illuminated by the Sun just below their horizon. It glowed brightly, an unmistakable smudge on the pitch sky, bright as a smear of paint on a black canvas. It was clear now why NASA had ensured that local radio stations had been warning people for a week of this launch series. The broadcasts had rightly said they would "light up the night sky from New England to Florida!"

But the pre-Aladdin launch was to be deceptive in its ease and clarity. When Saturday dawned the cloud was back, presaging problems yet to come.

What follows, I must impress, is written from the point of view of someone interested in only a narrow range of the Aladdin experiments. That range, although largely successful, suffered a proportion of failures that by interpolation may give a false impression about the success of the series

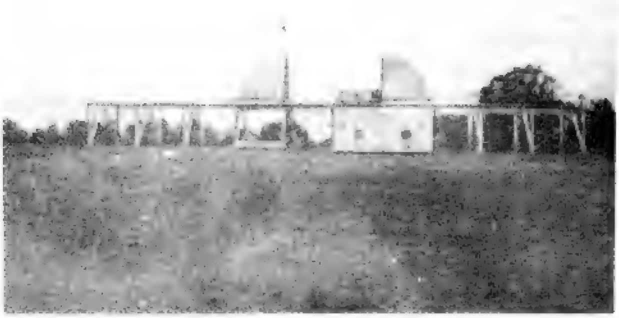


Fig. 2. Building U-40, Wallops mainland. One of UCL's optical sites. Dome halves shown partly separated.

Fig. 3. Ute-Tomahawk on the launch pad. This is one of the UCL vehicles, the ill-fated 16.00 launch. The Ute is the (fatter) booster.

overall. In fact, enough data was recovered to keep researchers busy until 1976.

From our viewpoint, though, there were disappointments. The first was at 12.40 on the Saturday when what was to have been the first rocket of the Aladdin series was cancelled 10 minutes before its scheduled firing time. It was a Lithium cloud release experiment, put off because all the ground sites were still enshrouded in the more common type of cloud. The NASA/AFCRL (Air Force Cambridge Research Labs) teams had apparently also decided not to trust to the instrumented aircraft alone. The next launch of significance was of an Aerobee 170. Its departure, in a great dense cloud, into the Virginia skies would be the irrevocable 'commit' to the full programme.

After the one Aerobee of the series came, in quick succession, two more of the major launches – the first carrying one of UCL's experiments. At 16.00 the Ute-Tomahawk roared into life. There is nothing graceful, in the Saturn 5 way, about a sounding rocket launch. A hideous row, a sudden blossoming of dense smoke, and it's gone before you know it, the growing line of exhaust smoke surmounted by a fast-moving glow that is visible long after the rocket itself. It had gone, and those of us interested sat back to await the results. At 16.16 the Germans' Black Brant was off. We did not know till later but this would carry the only mass spectrometer of the five in the series to be successful.

Then we heard the result of the 16.00 launch. Expected to reach 155 km, it had apparently only touched 99. This meant the AFCRL mass spectrometer and UCL E-field experiment would have sent little data of any use. This figure was later updated to 'perhaps' 110 km, more hopeful for the UCL experiment if not the other. The failure was due to nosecone separation taking place far too early, shown by the record of mass spectrometer pressure. The AFCRL scientists were left to discover the cause, since the telemetred records also showed that the 'eject' signal had come later, at the right time.

There had been a little previous discussion of the Ute-Tomahawk's "bad track record", mainly on keeping to a planned trajectory, but we were aware not too much should be read into this one failure. The U-T series was meant as a replacement for various Nike combinations since the numbers of surplus military vehicles had dwindled. The Ute had apparently not been fully tested as yet.

At five o'clock the second (17.20) Lithium release round was cancelled. Most of the rest of the programme seemed to have gone off well, apart from the failure of an NO release (to measure atomic oxygen by its interaction with NO) which was part of the payload of a Nike-Tomahawk.

The next point of direct interest to us lay in a series of four launches in quick succession just after dusk. All four were Ute-Tomahawks, the first and third Barium and TMA releases, the second and fourth ion mass spectrometers. Dusk approached and the skies began to clear; as the light started to fail the blue patches were growing, as if crowding the cloud from the sky. So, as the first of the four vehicles was launched at 21.06 there was only sky-mist to hinder observations, though it was thick enough to hide the stars. We stood, craning our necks to stare into a pitch-black sky. At Sandbridge the Georgia Tech. group's cameras started their operation sequence. The shutters and film winding mechanisms clattered and whirred as the old units sprang to life, sounding more like a spinning Jenny than precision optical equipment. The sound must have carried for miles across the quiet night-time dunes.

And then we saw it! A pale yellow ball appeared in the sky and started to expand, growing at its diffuse outer edge. This was the apogee Barium release. Below it other circles formed – the TMA puffs. These ended in a TMA trail, glowing blue by reflected sunlight. Any of this that still survived when the Sun had set at that height (90 to 150 km) would still glow, but this time white and somewhat dimmer as the energy source changed to chemiluminescence fed by a reaction with the ambient atomic oxygen. As the time passed the balls continued to expand and then started to fade as they became too diffuse to see. The TMA trail, like an over-fat aircraft contrail, started to snake as the vertical variation in winds acted differently on different parts of its length. The Barium separated into two clouds moving apart. One was yellowish – the neutral Barium being moved by the same winds as the TMA; the other was red – the ionised component moving under the action of a different set of forces,

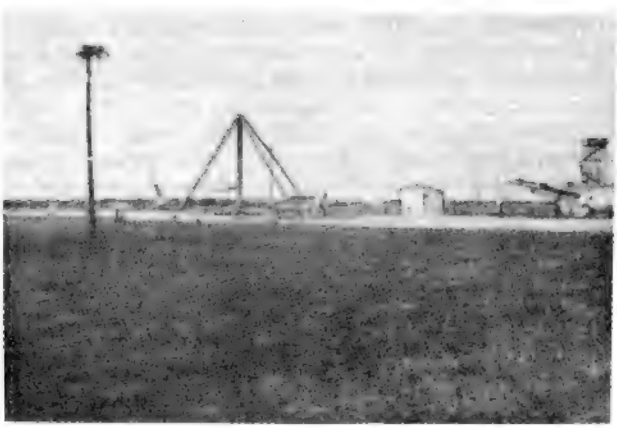


Fig. 4. Various Nike combinations on Pad 5 just prior to dummy countdown.

Fig. 5. W-40, the vehicle preparation building for four of the Pad 3B vehicles, some of which are shown in this picture.

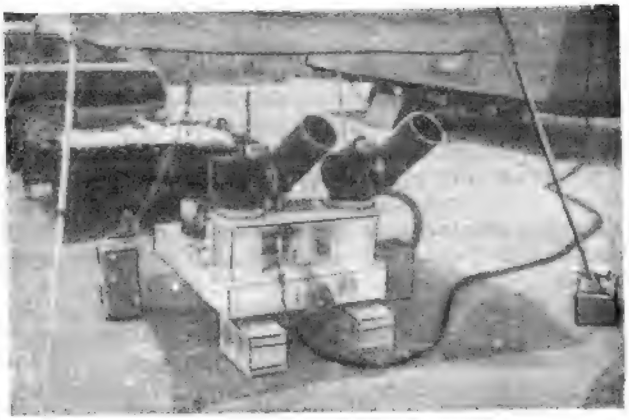


Fig. 7. The Sandbridge optical site. The cameras in the foreground were from Georgia Tech. Directly behind them is the trailer they also supplied, and through which came all communications. The building at the rear housed the UCL experiment (note notorious flap!). The caravan was for AFCRL personnel – their instrument was sited just to left of picture.

All illustrations Alan Farmer

Fig. 6. The two types of ground-based Lithium photometer for tracking daytime Na/Li releases: (a) AFCRL unit; (b) UCL unit.

electric fields.

Over the radio came news of another disappointment. The second U-T launched at 21.10 had had a second stage failure. But the site crews kept working, leaving their cameras running for the chemical releases at 21.26. As that time came, and we heard the launch had taken place, we looked again to the skies. A satellite was passing over. The Georgia Tech. team reported it, in case of questions later as to the origin of a white streak across some of their photos. Five minutes dragged by and we knew something was wrong. Confirmation came when Control announced the round had broken up. The fourth of the group was cancelled while consideration was given to the failures. (This vehicle was launched later that night but failed due to second stage instability).

Desultory comments were passed back and forth over the intercom net as a group met at Control to decide what to do next. Though the other launches were passing off fairly uneventfully, the advisability of going on with the Ute-Tomahawks was being discussed. Someone on the intercom started explaining that the Ute-Tomahawk configuration seemed to have a dynamic instability problem around the time of first stage burnout. The second stage, if this was true, could be released with, at least, poor pointing accuracy (apparently borne out by the 'successful' vehicles of the Aladdin series which had a standard deviation in azimuth heading of 10°) and, at worst, severe gyration which could cause it to tear itself apart.

A decision was reached. The next U-T would go ahead as planned, and the position reviewed depending on what happened to this. The launch occurred at 23.45. An experimental Na/Li release was planned for T + 70 sec., followed by a TMA trail. No cloud was seen, and the radar found itself tracking several pieces to 200 km. The vehicle had apparently performed faultlessly, but the experimental payload had exploded, destroying the vehicle. As the vehicle itself had not been at fault the decision was again deferred until

the next U-T launch. The rest of the cloud launches took place by this system of continual deferment. Fortunately, failures on the scale we had so far seen did not again occur and the rest of the releases took place.

The 01.58 launch of a TMA release went fairly well, though the release was 20° in azimuth out of position seen from Sandbridge. In the same round there was a photometer and a 7 in. sphere carrying a sensitive accelerometer for drag measurement, this latter giving atmospheric density. The 03.50 launch of the second UCL E-field experiment, piggy-backing an AFCRL payload of photometer and mass spectrometer, was cancelled in the light of the nose-cone ejection trouble on the similar 16.00 vehicle. A pre-dawn TMA and a dawn Ba/TMA round each flew as planned, though instead of TMA puffs followed by a trail on the latter, only a trail was seen because of a sticking valve.

With the relative success of the later Ute-Tomahawk launches things were now looking up for the two daytime Lithium releases, also on this vehicle type. The clear weather too seemed to be carrying on into the day. At Sandbridge, U-40 and Coquina Beach the UCL and AFCRL photometers were prepared, while the camera crews packed up, their job complete.

First Na/Li release launch was due at 08.55. It was Sunday morning and elsewhere Americans were getting up to go to church or wash the car. At Wallops, Sandbridge and Coquina Beach crews which had been on the alert on and off since midday the previous day were ready to play out the last four hours of Aladdin '74.

At Sandbridge the Sun would be close in the sky to the projected release position, and this, together with a bad gradient of colour over the early morning sky, and patchy high-level mist made observations difficult. Then a sudden change in launch azimuth/elevation settings meant a last minute rush to change instrument look-directions. Suddenly, the rocket had been launched! From the disappointed lethargy of the day before, for a short period there was a change to constant action. Instruments were turned on, checked, adjusted, readings balanced and functions monitored. At U-40 a fairly clear signal was identified. At Sandbridge the AFCRL instrument seemed to be tracking well, but there was so much 'noise' from the sky it was hard to see anything significant on the UV paper print-out of the UCL unit. A proper picture would have to wait for detailed analysis of the results later.

As this experiment came to an end, instruments were reset for the next. Originally to have been at 12.55, this was rescheduled for 13.20, as U-40 reported it would otherwise give a release too near the Sun in their sky. This was the latest it could be sent off with present range availability. The release was also changed from a downleg one to upleg to make it less susceptible to vehicle mis-performance. If it did not reach sufficient altitude as planned a downleg release could occur too low to be useful.

The 13.20 launch passed off like the previous one, except this time the Sandbridge UCL unit announced an apparently clear scan, while at U-40 only a few minutes useful readings were taken, with the dome drawn up as a sun-shield. As the 30 minutes after the launch passed the units one by one stopped recording. This rocket had been the last in the Aladdin series. It seemed strange to be finished, as if the more an event was awaited the more substantial it was expected to be. Or perhaps it was just hard to change out of the mood of constant preparation. After a pause the ground sites started to compare notes over the intercom, at the same time as they prepared to pack up.

Home Again

Compared to the build-up, the run down from the campaign took place swiftly. There was a brief period of packing and sending the instruments off. A post-launch meeting, and soon the experimenters, engineers and ground crews were dispersing. But the time before we left was marked for me by two 'incidents'.

The first was the 'Jeux sans Frontieres' type effort to get the front-wall flap back up on the Sandbridge building. It was first pulled up using the sliding roof, but then had to be pushed the final few inches by a beam levered by the Georgia Tech. instrument truck. Why is it that applying basic physics in such simple ways is often more satisfying than some of the more esoteric moments?

The second event seemed almost to have been laid on to prepare the small English contingent for their home-going. At Wallops Base there was a strike in the workshops. Yes, they do happen in America, too! The pickets outside the fence seemed almost to be seeing us off as we started the long journey back *via* Washington.

INTERNATIONAL ASTRONAUTICS AWARD

The Daniel and Florence Guggenheim International Astronautics Award for 1974 has been given to Professor Hilding A. Bjurstedt, Head of the Department of Aviation Medicine at the Karolinska Institutet in Stockholm (Sweden). The Award is given each year by the International Academy of Astronautics to an individual who has made an outstanding contribution to space research and exploration through work done during the preceding five years. It is accompanied by a stipend of $1,000.

Announcing the Award, which was presented to Professor Bjurstedt during the 25th International Congress in Amsterdam, Dr. C. Stark Draper, president of the International Academy of Astronautics, gave in resumé of Dr. Bjurstedt's extensive research on response of bodily functions to long-term acceleration, changes in the pressure and composition of the ambient atmosphere, and other environmental stress factors. The work carried out in his laboratory under his direction includes studies of mechanisms involved in the chemical and nervous control of respiration and circulation, dynamics of cardiorespiratory adaptation to altered environments, and development of special instrumentation and electronic data processing.

Dr. Bjurstedt began his career at the Karolinska Institutet in 1939 as an instructor and research assistant in the Department of Physiology. In 1946 he became Head of the Department of Aviation Medicine and also lecturer in physiology and professor of aviation medicine. In 1950, he was awarded a fellowship by the Rockefeller Foundation for studies of the physiology of respiration at the University of Rochester School of Medicine, New York. He spent most of the year 1966 at the University of California at Berkeley as Visiting Professor in the Department of Physiology.

The importance of Prof. Bjurstedt's achievements has been widely recognized and has contributed to his active involvement in many international scientific meetings and committees concerned with space medicine and manned space flights.

DELTA – THE 100-PLUS LAUNCH VEHICLE

By Mike Howard

Introduction

Echo, TIROS, OSO, Telstar, Relay, Syncom, ESSA, Pioneer, Early Bird, INTELSAT, Biosatellite, Explorer, ERTS, Nimbus: What do all these differing types of satellites have in common? The answer is the Delta launch vehicle. In the years since 1960 Delta vehicles have placed over 100 satellites in widely varying orbits with a success rating of over 90 per cent. Satellites have ranged in weight from 79 lb. (Explorer 10 - 25 March 1961) to 2070 lb. (ERTS-1 - 23 July 1972).

Delta's History

During 1959-60 Thor-Delta was planned as an intermediate launch vehicle which would be used temporarily until more sophisticated vehicles were available. At that time the vehicle was comprised of a U.S. Air Force Thor first stage and improved U.S. Navy Vanguard second and third stages which made up the Delta. Today that same basic combination, with various improvements over the years, is still in use.

The first Delta launch, on 13 May 1960 of the Echo passive communications sphere, was one of the few failures that the vehicle has experienced. On its second launch almost exactly three months later Delta placed the first successful Echo in a 1,000 mile (1600 km) circular Earth orbit. From then on there was to be no looking back as Delta vehicles launched weather satellites, solar observatories, recoverable biological satellites, countless Explorer spacecraft, and yet more communications satellites.

During the years from 1960 to 1965 most of the 35 launches were for NASA and included the first Pioneer to orbit the Sun and paved the way for today's multi-million dollar commercial communications satellite industry by successfully placing NASA's Syncom into the first synchronous orbit.

Over the next few years – 1966 to 1969 – a further 39 launches occurred, an ever increasing number of which were on a reimbursable basis for foreign and commercial users. Included in this number were six TOS meteorological satellites for the National Oceanic and Atmospheric Administration (NOAA). From 1970 to 1973, 25 Deltas brought the launch total to 99.

Scheduled 1974 Launches

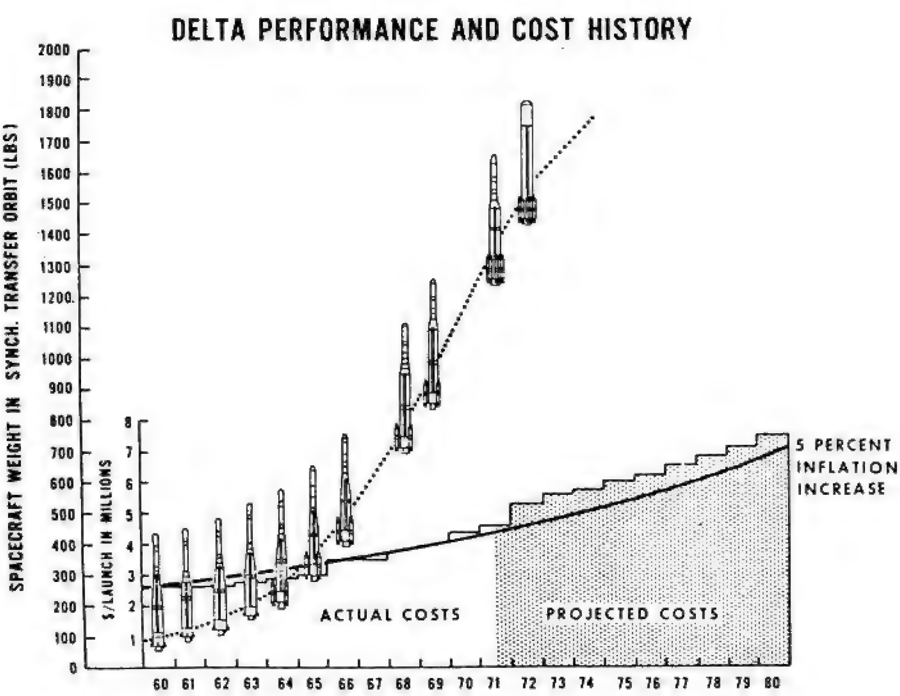
WESTAR B	June
SMS B	July
JTOS G	July
GOES A (SMS C)	August
SKYNET 2-B	3rd Quarter
WESTAR C	October
NIMBUS F	October
COMSAT A	4th Quarter
SYMPHONIE A	4th Quarter

On 18 January 1974 Delta 100 lifted off from Kennedy Space Center's complex 17 carrying the UK military comsat Skynet-IIA. Unfortunately what should have been a memorable occasion was marred when a short circuit in the second stage electronics package caused one of Delta's rare failures.

Since that 100th launch and up to the time of writing two further missions have used the Delta successfully – Westar-A (the first U.S. commercial domestic communications satellite) and SMS-A (the first geosynchronous weather satellite).

The popularity of the Delta booster has enabled it to ease the U.S. balance of payments by some $60 million. During the next five years an estimated further $80-100 million will be paid to the U.S. by other nations requiring the services of the Delta vehicle.

Apart from its reliability, one of the major attractions of the Delta hardware is that its cost over the last 13 years has risen at a rate not much greater than the compounded inflation rate of 5 per cent a year even though the vehicle's payload capability has increased tenfold over the same period.



Delta Performance and Cost History. The launch vehicle's remarkable development programme already spans 15 years. It is likely to continue well into the 1980's.

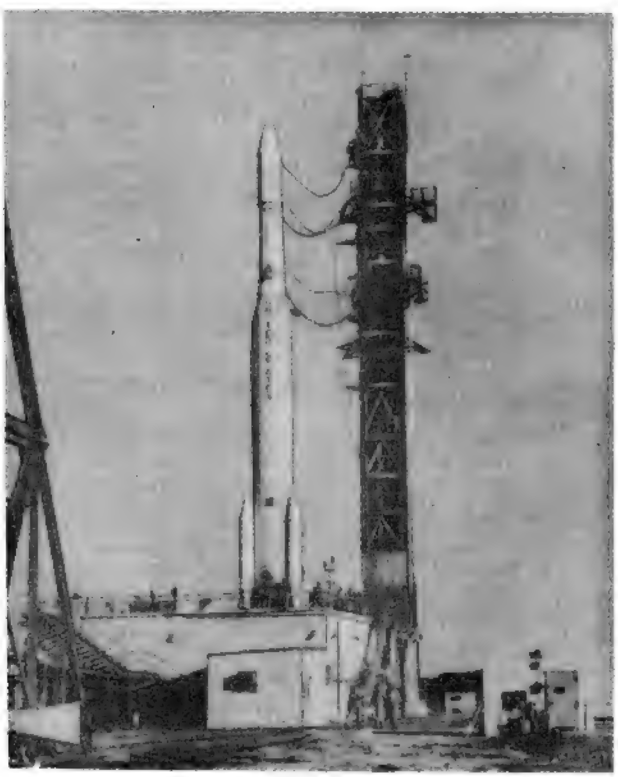
National Aeronautics and Space Administration

In 1960 the Delta was capable of placing a 150 lb. (68 kg) payload in a synchronous transfer orbit whereas the possible weight is now 1,500 lb. (680 kg). For a low Earth orbit the payload has increased from 525 lb. (240 kg) to 4,000 lb. (1920 kg). Considering hardware and launch services alone the costs for a low Earth orbit have effectively been cut from approximately $5,000 to $1,600 per pound. At the present time Delta vehicles are launched from Complex 17 at KSC, Florida and SLC-2 at the Western Test Range, California. McDonnell Douglas Astronautics Co., Huntington Beach, California, is the Delta vehicle and launch services prime contractor with programme management under the control of the Goddard Space Flight Center, Greenbelt, Maryland. The cost of the Delta programme, excluding development, to the end of June 1973 was $363.7 million.

Vehicle Description

As previously stated the Delta vehicle is used for a wide variety of medium-size satellites and small space probes. To achieve the most economical and effective launch capability the Delta may be used as a two- or three-stage vehicle with three, six, or nine solid rocket motors (SRM's) to augment the first-stage thrust.

The three-stage Straight-Eight Delta (so named for its constant 8-ft. diameter) has the following characteristics:



Long Tank Delta, on the launch platform at the Kennedy Space Center, being prepared to launch the 632 lb. Intelsat 3 communications satellite into geo-stationary orbit above the Pacific on 5 February 1969. In its active nine-year history, Delta had recorded a 94 per cent launch success rate while orbiting the majority of U.S. scientific, weather and communications satellites.

McDonnell Douglas Astronautics Company

Height (including shroud): 116 ft. (35.4 m.).
Maximum Diameter: 8 ft. (2.4 m.) without SRM's.
Lift-off weight 116 tons (106,000 kg).
Lift-off thrust: 305,000 lb. (including 3 SRM's).

First Stage (excluding SRM's):
Extended Long-Tank Thor –

Height, 70 ft. (21.3 m.).
Diameter, 8 ft. (2.4 m.).
Thrust, 205,000 lb.
Propellent, RJ-1 kerosene as fuel and LOX as oxidizer.
Burning time, 228 secs.
Weight, approx. 93 tons (84,700 kg).

Thor is produced by McDonnell Douglas Astronautics Co., engines by Rocketdyne division of Rockwell International.

Strap-on Solids:
3, 6, or 9 Solid Propellent Rockets –

Height, 19.8 ft. (6.0 m.).
Diameter, 31 in. (0.8 m.).
Thrust, 52,000 lb. each.
Burning time, 38 sec.
Weight, 4,470 kg each.

Produced by Thiokol Chemical Corporation.

Second Stage:
Delta –

Height, 21 ft. (5.2 m.).
Diameter, 5 ft. (1.5 m.) excluding ring.
8 ft. (2.4 m.) with ring.
Thrust, 9,500 lb.
Propellent, Aerozene 50 as fuel and nitrogen tetroxide as oxidizer.
Burning time, 335 secs.
Weight, 6.8 tons (6,210 kg).

Produced by McDonnell Douglas Astronautics Company.

Third Stage:
TE-364-4 –

Height, 4.5 ft. (1.83 m.).
Diameter, 3 ft. (1.0 m.).
Thrust, 9,500 lb.
Propellent, solid.
Burning time, 44 sec.
Weight, 1,592 lb. (722 kg)

Produced by Thiokol Chemical Corporation.

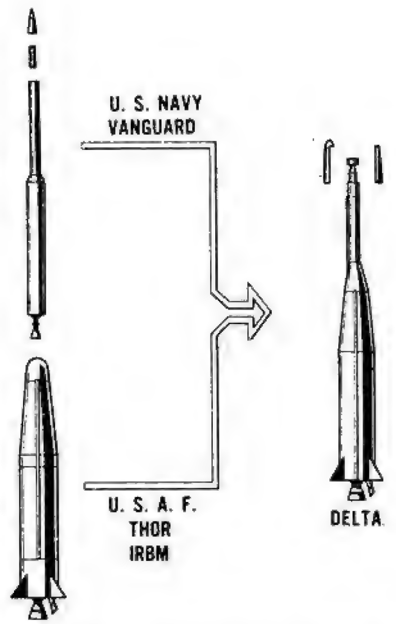
Hamilton-Standard and Teledyne are major contractors for the vehicle inertial guidance system located on the second stage.

Delta's Future

After 14 years of 'temporary' service the Delta is more popular than ever. So far in 1974 three missions have been launched with a further 25 confirmed flights scheduled for the 1974-75 launch calendar. These missions include the now familiar domestic and global communications satellites, and meteorological satellites, several of which are for foreign and commercial users.

It seems that the Delta launch vehicle, one of NASA's

DELTA ANCESTRY



National Aeronautics and Space Administration

most utilized workhorses, will be in the stable for many years to come.

Acknowledgement

The writer wishes to thank Charles R. Chappell of the McDonnell Douglas Astronautics Company for his assistance in the preparation of this article.

Delta Launch Vehicle Log

Delta No.	Payload	Weight(lb)	Launch Date	Pad
1	ECHO	180	13-05-60	17A
2	ECHO 1A	182	12-08-60	17A
3	TIROS A2	277	23-11-60	17A
4	EXPL-10 (p-14)	79	25-03-61	17A
5	TIROS A3	285	12-07-61	17A
6	EXPL-12 (S-3)	84	15-08-61	17A
7	TIROS 4	285	08-02-62	17A
8	PSP 1 (S-16)	458	07-03-62	17A
9	ARIEL 1 (S-51 UK1)	136	26-04-62	17A
10	TIROS 5 (F)	286	19-06-62	17A
11	TELSTAR 1 (TSX1)	171	10-07-62	17B
12	TIROS 6 (F)	280	18-09-62	17A
13	EXPL-14 (S-3A)	86	02-10-62	17B
14	EXPL-15 (S-3B)	98	27-10-62	17B
15	RELAY A-15	170	13-12-62	17A
16	SYNCOM A-25	146	14-02-63	17B
17	EXPL-17 (S-6)	410	02-04-63	17A
18	TELSTAR 2 (TSX2)	176	07-05-63	17B
19	TIROS 7 (G)	296	19-06-63	17B
20	SYNCOM B (A-26)	147	26-07-63	17A
21	EXPL-18 (IMP A)	138	26-11-63	17B
22	TIROS 8 (H)	265	21-12-63	17B
23	RELAY 2 (A-16)	184	21-01-64	17B
24	S-66	132	19-03-64	17A
25	SYNCOM C	145	19-08-64	17A
26	IMP B	135	03-10-64	17A
27	S 3C	101	21-12-64	17A
28	TIROS I (EYE)	301	22-01-65	17A
29	OSO B2	547	03-02-65	17B
30	COMSAT HS303A	149	06-04-65	17A
31	IMP C	128	29-05-65	17B
32	TIROS OT 1	280	01-07-65	17B
33	OSO C	625	25-08-65	17B
34	GEOS A	387	06-11-65	17A
35	PIONEER A	146	16-12-65	17A
36	OT 3	304	03-02-66	17A
37	OT 2	286	28-02-66	17B
38	AE B	492	25-05-66	17B
39	IMP D	212	01-07-66	17A
40	PIONEER B	138	17-08-66	17A
41	TOS A	316	02-10-66	SLC2E
42	INTELSAT 2 A (F-1)	355	26-10-66	17B
43	BIOS A	950	14-12-66	17A
44	INTELSAT 2 B (F-2)	357	11-01-67	17B
45	TOS B	285	26-01-67	SLC2E
46	OSO E1	600	08-03-67	17A
47	INTELSAT 2 C (F-3)	365	22-03-67	17B
48	TOS C	327	20-04-67	SLC2E
49	IMP F	163	24-05-67	SLC2E
50	AIMP E	230	19-07-67	17B
51	BIOS B	955	07-09-67	17B
52	INTELSAT 2 D (F-4)	357	27-09-67	17B
53	OSO D	605	18-10-67	17B
54	TOS D	299	10-11-67	SLC2E
55	PIONEER C	146	13-12-67	17B
56	GEOS B	469	11-01-68	SLC2E
57	RAE-A	602	04-07-68	SLC2E
58	TOS E	347	16-08-68	SLC2E
59	INTELSAT 3 A (F-1)	641	18-09-68	17A
60	PIONEER D	147	08-11-68	17B
61	HEOS A	237	05-12-68	17B
62	TOS APT F	297	15-12-68	SLC2E
63	INTELSAT 3 C (F-2)	642	18-12-68	17A
64	OSO F	645	22-01-69	17B
65	ISIS A	532	30-01-69	SLC2E
66	INTELSAT 3 B (F-3)	642	05-02-69	17A
67	TOS G	347	26-02-69	17B
68	INTELSAT 3 D (F-4)	647	21-05-69	17A
69	IMP G	175	21-06-69	SLC2W
70	BIOS D	1546	28-06-69	17A
71	INTELSAT 3 F (F-5)	647	25-07-69	17A
72	OSO G	647	09-08-69	17A
73	PIONEER E	148	27-08-69	17A
74	SKYNET A	535	22-11-69	17A
75	INTELSAT 3 F (F-6)	647	14-01-70	17A
76	TIROS M	682	23-01-70	SLC2W
77	NATO A	535	20-03-70	17A
78	INTELSAT 3 G (F-7)	647	22-04-70	17A
79	INTELSAT 3 H (F-8)	647	23-07-70	17A
80	SKYNET B	535	19-08-70	17A
81	ITOS A	680	11-12-70	SLC2W
82	NATO B	533	02-02-71	17A
83	IMP I	635	13-03-71	17A
84	ISIS B	570	01-04-71	SLC2E
85	OSO H	1416	29-09-71	17A
86	ITOS B	687	21-10-71	SLC2E
87	HEOS A2	260	31-01-72	SLC2E
88	TD 1A	1043	12-03-72	SLC2E
89	ERTS A	2070	23-07-72	SLC2W
90	IMP H	860	23-09-72	17B
91	ITOS D	742	15-10-72	SLC2W
92	TELESAT A	1238	10-11-72	17B
93	NIMBUS F	1574	11-12-72	SLC2W
94	TELESAT B	1238	20-04-73	17B
95	RAE B	734	10-06-73	17B
96	ITOS E	747	16-07-73	SLC2W
97	IMP J	876	26-10-73	17B
98	ITOS F	746	06-11-73	SLC2W
99	AE C	1494	16-12-73	SLC2W
100	SKYNET 2-A	285	18-01-74	17B
101	WESTAR A	1265	13-04-74	17B
102	SMS A	1379	16-05-74	17B
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SATELLITE DIGEST — 78

A monthly listing of all known artificial satellites and spacecraft, compiled by Robert D. Christy. Information is based on that supplied by the Space Department of the Royal Aircraft Establishment, Farnborough and other sources. For information on the derivation of orbital parameters, abbreviations, etc., see July issue, p. 262.

Continued from December issue, p. 473.

Name, designation	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclination (deg)	Nodal period (min)	Launch centre, launch vehicle and payload/launch origin
Soyuz 14 1974-51A	1974 Jul 3.79 15.72 days (R) 1974 Jul 19.51	Sphere + cone-cylinder + antennae	7.5 long 2.2 dia	195 268	217 271	51.58 51.58	88.55 89.84	Tyuratam-Baikonur Soyuz USSR/USSR (1)
Meteor 18 1974-52A	1974 Jul 9.61 500 years	Cylinder + 2 vanes + antennae	5 long? 1.5 dia?	865	893	81.23	102.57	Plesetsk USSR/USSR
Cosmos 666 1974-53A	1974 Jul 12.54 12.7 days (R) 1974 Jul 25.2	Sphere-cylinder 4000?	5 long? 2 dia?	181	328	62.81	89.59	Plesetsk USSR/USSR
1974-53D	1974 Jul 12.54 17.69 days 1974 Jul 30.23	Sphere?	2 dia?	168	308	62.82	89.25	Plesetsk USSR/USSR (2)
NTS 1 1974-54A	1974 Jul 14.22 indefinite	Octagon + 4 vanes 293 (unfuelled)	0.56 long 1.22 dia	13445	13767	125.08	468.40	WTR NASA/NASA
Aeros 2 1974-55A	1974 Jul 16.49 8 months	Cylinder 127	0.74 long 0.91 dia	224	869	97.45	95.60	WTR W.Germany/NASA (3)
Molniya-2K 1974-56A	1974 Jul 23.06 5 years?	Cylinder-cone + 6 panels + 2 antennae 1250?	4.2 long? 1.6 dia?	604 505	40726 39871	62.89 62.90	737.59 718.17	Plesetsk USSR/USSR (4)
Cosmos 667 1974-57A	1974 Jul 25.29 12.9 days (R) 1974 Aug 7.2	Sphere-cylinder 4000?	5 long? 2 dia?	176	320	64.98	89.46	Tyuratam-Baikonur USSR/USSR
1974-57D	1974 Jul 25.29 24 days 1974 Aug 18	Sphere?	2 dia?					Tyuratam-Baikonur USSR/USSR (5)
Cosmos 668 1974-58A	1974 Jul 25.50 7 months	Ellipsoid 400?	1.8 long? 1.2 dia?	176	320	70.95	92.20	Plesetsk USSR/USSR
Cosmos 669 1974-59A	1974 Jul 26.29 12.83 days (R) 1974 Aug 8.12	Sphere-cylinder 4000?	5 long? 2 dia?	209	230	81.32	88.91	Plesetsk USSR/USSR
1974-59G	1974 Jul 26.29 16 days 1974 Aug 11	Sphere?	2 dia?	201	225	81.33	88.78	Plesetsk USSR/USSR (6)
Molniya S 1 1974-60A	1974 Jul 29.50 indefinite	Cylinder-cone + 6 panels + 2 antennae 1250?	4.2 long? 1.6 dia?	340 35850	35274 35850	48.49 0.07	632.35 1439	Tyuratam-Baikonur USSR/USSR (7)
Molniya S 1 launch platform 1974-60B	1974 Jul 29,50 3 days 1974 Aug 1	irregular		183	195	51.49	88.21	Tyuratam-Baikonur USSR/USSR (8)

Supplementary Notes:

(1) The first attempt to place a crew aboard Salyut 3 (1974-46A). Cosmonauts Pavel Popovitch and Yuri Artyukhin docked the two spacecraft at 1974 Jul 4.9 and undocked at 1974 Jul 19.4.

(2) Ejected from 1974-53A during 1974 Jul 24.

(3) Second West German aeronomy satellite, designed to collect data on the upper atmosphere over a six month period. Data collected will supplement the results obtained during the first half of 1972 by Aeros 1.

(4) Orbital data at 1974 Jul 24.1 and 1974 Jul 27.7.

(5) Ejected from 1974-57A during 1974 Aug 6.

(6) Ejected from 1974-59A during 1974 Aug 7.

(7) First Molniya satellite to be placed in stationary orbit. A test vehicle was launched earlier under the name os Cosmos 637 (1974-17A.) Orbital Data at 1974 Jul 29.5 and 1974 Jul 30.5

(8) Launched Molniya S 1 from initial parking orbit.

BOOK REVIEWS

Beyond the Known Universe: from Dwarf Stars to Quasars
By I. M. Levitt, The Viking Press Inc., N.Y., 1974, pp. xi + 131, $10.00

I suppose it is fair to say that the dramatic and enigmatic events in astronomy which, since the discovery of the quasars a mere dozen years ago, sent the scientific community reeling, can all too easily pass the layman by. Possibly this is due not so much because the layman is unaware of their existence (the popular media are always ready to scoop the 'big' discoveries in science and technology, even if inaccurately!) but due to the fact that there is a lack of good and up-to-date authoratative texts. While the professional astronomer is certainly well catered for, these publications are incomprehensible to the amateur, and not infrequently so to the professional!. It is refreshing, therefore, to see a single volume devoted specifically to the layman and where no basic knowledge is required to appreciate the enormous advances in astronomy (both scientific and financial!) over the past decade or more.

Although the title is rather misleading – the subject matter is not so much beyond the known universe as at the very extremes of our present knowledge and physical concepts – Dr. Levitt's style is exemplary, being both delightfully lucid and, at the same time, authoratative. The problem of drawing together such exotic topics ranging from elementary particles to black holes into a single, relatively brief yet readily comprehensible picture is masterfully conducted by the author. Of course drastic simplification is often necessary, but in such complex fields as these this is only to be expected. Levitt offers explanations of terms which will clearly be foreign to the layman, and demonstrates a skilful ability in drawing easily understandable analogies when describing objects, conditions, sizes etc., alien to everyday experience.

The author begins with a discussion on particles and radiations of which a star is composed and develops this through stellar evolution to the extreme states of matter found in white dwarfs, supernovae, neutron stars, pulsars, and the currently fashionable black holes. A final chapter deals with the incongruous quasars.

This book should certainly be valuable in up-dating the amateur's appreciation of recent trends and discoveries in various fields of astronomical research. Although quite short, the high degree of concentration of subject matter deals admirably with matter subjected to concentration of a high degree!

S. G. SYKES

Apollo 17 Preliminary Science Report
NASA SP-330 Scientific and Technical Information Office, National Aeronautics & Space Administration, 1973, pp. 712, $7.95.

This impressive volume is no unpalatable assemblage of mathematics and technical jargon but an absorbing, profusely illustrated presentation designed to make its scientific content digestible at all levels, and which demands a place in any astronomer's or space buff's library. Its contributors are those most closely connected with the design and operation of the experiments – the Principal Investigators, the astronauts themselves, the contactors and members of the teams examining samples and other returns – which makes the information very reliable, but virtually impossible to confirm as some results are published here for the first time.

The many pages of text are not exclusively 'results'; a large slice of the book is devoted to explanation of the working of the items of experimental equipment, the significance of the data returned, and providing the background knowledge needed to understand the text and the thousands of lucid diagrams. This applies, particularly, to the detailed Mission Description and Landing Site Selection sections, which hold the book together.

There is a splendid Photographic Summary, including 61 colour shots, which gives a camera's-eye view of the flight from midnight launch to Pacific splashdown.

Every detail is thoroughly examined; each important moonrock, for example, is shown as photographed in the laboratory, as seen on the moon (with diagrams indicating the important features) and with the on-the-spot description of the crew. The composition and age will be found in another section, its overall significance in a third and so forth – but there is no index, and finding everything on one subject proves difficult.

One appendix this reviewer found particularly interesting was a set of panoramic photographs taken at sampling stations and other points of interest; one of them being a mosaic of TV views. This is one of only two places where TV shots are used (the other showing the LM lift-off) and, although the television observations were very carefully planned to bring out information missed by and complementary to that of the astronauts, no contributor makes more than the briefest reference to this important experiment.

More serious, no consistent system of units is used (cgs, mKs and avoirdupois are all found) and the serious student may be hampered in trying to integrate results from different sections. A further drawback, which applies to members ordering outside the US, is that it is available only from the Superintendant of Documents of the Government Printing Office Public Documents Dept. (Washington DC 20402) at $9.95; the extra $2 covering foreign p & p. A considerable delay, typically 6 months, can be expected before the book is received.

ROBERT C. EDGAR

Artificial Satellite Observing
Ed. By Howard Miles, Faber & Faber 1974, pp. 126, £5.50.

Making accurate visual observations of artificial Earth satellites is one area where the amateur can still make a genuine contribution to scientific research. This book is highly recommended for those engaged in, or contemplating such a pursuit.

Edited by Howard Miles, who performs the useful service of training would-be observers to the required standard of proficiency, the book contains eight chapters by seven authors, among them noted amateur observers. In addition, the eight Appendices are a mine of information about satellite brightness, time signals, orbital theory, etc., together with a concise account of professional tracking techniques.

Particularly fascinating is the chapter by Dr. King-Hele explaining how observations are used to provide accurate orbits and how orbital changes are used in geophysical research – to provide upper atmosphere density and rotation and also the zonal harmonic coefficients of the Earth's gravitational field.

Recommended, too, is the account by Kettering Grammar Schoolmaster, Geoffrey Perry, of his notable work in radio

tracking, particularly of shortwave transmitting Russian spacecraft and he gives excellent descriptions of Doppler tracking and telemetry types. His table of VHF transmission frequencies indicates that the book has, unfortunately, suffered publication delays, but his account has dated little and he correctly predicts the continued application of shortwave in the Soviet manned spaceflight programme (e.g. Salyut 3), though biomedical subcommutation of Word 4 of Soyuz PDM telemetry may no longer be valid.

Coverage is also given of observing techniques, including how to prepare predictions and how to make and report observations. The method described for preparing predictions from an assumed inclination and period with a known launch time is useful and has been successfully used for early observations of Soyuz 8 and Soyuz 9 close to their respective carrier rockets. Had cloud not interfered it would no doubt have also worked for Soyuz 6, 7, 12, 13, 14 and 15, all of which were visible from Britain within nine hours of launch.

My only criticism of the book is that the first two chapters could have been shorter to allow more coverage of actual observing techniques, including telescopic observation. More emphasis might then have been placed on short cuts in preparing to observe e.g. use of a large scale planisphere to convert Altitude/Azimuth to Right Ascension/Declination and of simple graphical techniques to derive eclipse positions from the satellite height and Earth's shadow angle.

DAVID G. HAWKINS

'Our World in Space'
By Isaac Asimov and Robert McCall, Patrick Stephens Ltd., 176 pp. 67 colour plates, £6.95, 1974.

If financial crises, industrial disputes, terrorism and other similar symptoms of today's world get you down, then pick up this book and what you will find within concerning what man has already achieved in space, and what he is contemplating, will restore your faith in humanity. It is an enthralling and inspiring book but yet one would expect nothing less with the text written by an author of the calibre of Isaac Asimov and the illustrations by official NASA artist Robert McCall, who was also the Art Director on '2001'.

It deals, initially, with our present position in space after the success of the Apollo and Skylab programmes. Indeed, it could scarcely be more up to the minute as included are descriptions and illustrations of the repairs necessary to make Skylab function so successfully. But the majority of the book looks to the future, both the immediate future for which hardware is already being designed, and to the long term future, to the full exploration of the Solar System and beyond. However, there is one idea in the author's envisualisation of the long term exploration of space on which I must disagree and that is that once Earth has colonised the Moon, Mars and the Asteroids, we will more or less withdraw from further exploration and leave it to the low-gravity and zero-gravity men of these colonies to continue outward. I cannot believe that '1G' man will ever sit back and let others continue with this adventure. In fact, if anything, people who will have spent their lives in the heavy gravity situation of Earth will be able to colonise far more than the low-gravity and particularly the zero-gravity men, whom, after a few generations, might find even Earth's gravity quite intolerable. However, to argue with the author is not to criticise the book as surely one of the aims of such a book is to provoke thought and discussion.

The time-scale over which exploration of the Solar System takes place is also another point of dispute, but yet, who would have said in the beginning of the sixties that by the end of the decade, Moon landings would have become commonplace and little cause for comment. It is significant that no fanciful propulsion systems are considered, nor in fact any techniques which do not exist at this moment, at least in principle. In fact, all proposals are examined from the position of a Devil's Advocate, and suggestions as to what might come to pass are only made after many 'ifs'.

Finally on a more mundane level, one would expect to pay for such a lavishly illustrated book; with 67 colour plates out of 174 pages, it is excellent value for money.

ANDREW ALLARDYCE

The Mitchell Beazley Concise Atlas of the Universe
By. P. Moore, Mitchell Beazley, 1974, pp. 190, £9.50.

This is a revised and updated edition of the version previously published under the title of *Atlas of the Universe*. It is a large-format illustrated book, many of the pictures being in colour, making extensive use of photographs from NASA. It is divided into four main parts i.e. Atlases of the Earth (from space), the Moon, Solar System and Stars, respectively.

The text is relatively slight and easily digestible, the main impact coming from the pictorial content. Many people will want to possess the volume for that reason alone.

The section on the Stars includes a variety of star maps plus descriptive text on some of the interesting objects in the night sky, photographed through the world's largest telescopes.

Similarly, the Atlas of the Moon includes a number of charts, plus a selection of pictures taken on various Lunar missions.

P. R. FRESHWATER

NASA ABSTRACT JOURNAL

By arrangement between NASA and the Smithsonian Science Information Exchange, a special section listing new and on-going aerospace related research projects has been added as a regular feature to NASA's bi-monthly abstract journal, *Scientific and Technical Aerospace Reports (STAR)*.

The new section, first published in the 23 August 1974, issue of *STAR*, will enable researchers in aerospace and related fields to become aware of on-going research projects. It lists titles of active NASA grants and university contracts, notices of non-NASA research projects, and summaries of recently up-dated *NASA Research and Technology Operating Plans*. Abstracts relating to non-NASA projects are provided by the Smithsonian Science Information Exchange.

NASA officials estimate that about 5,400 items will be reported annually in the special section. Additional information may be obtained from the Scientific and Technical Information Office, Code KSS, NASA, Washington, D.C. tel: 202/755-3464.

1975 SUBSCRIPTIONS

Members are reminded that the 1975 subscriptions will fall due for renewal on 1st January, 1975.

The rates are as follows:-

	Sterling	*US Dollars*
Student Members	£4.50	$12.50
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The above fees include the receipt of *one* of the Society's publications, i.e. the *Journal* or *Spaceflight*. A further £4.50 ($12.50) should be added where members wish to receive *both* publications.

The Student Member rate of £4.50 ($12.50) applies only to Members under the age of 21.

Fellows, Associate Fellows, Senior Members, and Members who have attained the age of 65 years on 1 January 1975 can, if they wish, claim a reduction of £1 from their annual subscriptions.

Remittances should now be sent to:-

The British Interplanetary Society,
12 Bessborough Gardens, London SW1V 2JJ.

EQUIPMENT

APPEAL FUND

We should like to extend our grateful thanks to all those members who responded to the President's letter appealing for funds to help the Society purchase composing equipment.

We are doing everything possible to maintain the present level of our publications, without raising membership dues, but rising costs have raised, yet again, the problems of financing further capital expenditure on printing facilities, particularly if we are successful in finding offices at a cost we can afford, yet which provide the additional facilities we need.

So, if you have not already done so, will you please contribute now, and generously. Your donation is badly needed and will be most welcome.

Please address your gift to:

The Executive Secretary,
British Interplanetary Society,
12 Bessborough Gardens,
London, SW1V 2JJ.

Spaceflight

Spaceflight is published monthly for the members of the British Interplanetary Society.

Full particulars of membership may be obtained from the Executive Secretary at the Society's offices at 12, Bessborough Gardens, London, SW1V 2JJ: Tel: 01-828 9371.

Correspondence and manuscripts intended for publication should be addressed to the Editor at 12, Bessborough Gardens, London, SW1V 2JJ.

Opinions in signed articles are those of contributors, and do not necessarily reflect the views of the Editor or the Council of the British Interplanetary Society, unless such is expressly stated to be the case.

Further meetings are currently being arranged for later sessions. Members who would like to present papers to General Meetings, Main Meetings, or contribute to Space Study Meetings, are invited to write to the Executive Secretary, British Interplanetary Society, 12, Bessborough Gardens, London, SW1V 2JJ.

Space Study Meeting

Titles: (a) **RECEPTION OF CLOUD-COVER PICTURES FROM SATELLITES** by A. J. Metheringham

(b) **RADIO MONITORING OF SATELLITE TRANSMISSIONS** by G. E. Perry

To be held in the Kent Room, Caxton Hall, Caxton Street, London, S.W.1. on **15 January 1975**, 6.30-8.00 p.m.

One doesn't always need highly-sophisticated equipment to obtain good data from satellite signals. This has already been demonstrated many times by keen amateurs using relatively simple and inexpensive apparatus.

Our two speakers will describe equipment available to many educational establishments and show, with examples, how this can be used as a basis for sound student projects.

Admission tickets are not required. Members may introduce guests.

Symposium

Theme **STARSHIP STUDY REPORT**

To be held in the Tudor Room, Caxton Hall, Caxton Street, London, S.W.1. on **26 February 1975**, 6.30-8.00 p.m.

Admission tickets are not required. Members may introduce guests.

Film Show

A Programme of New Films on the theme of **SKYLAB** will be held in the Botany Lecture Theatre, University College, Gower Street, London, W.C.1. on **11 March 1975**, 6.30-8.30 p.m.

The Programme will be as follows:-

(a) Skylab: The Search & The Hope
(b) Skylab: Mission Made Possible
(c) Skylab: The Second Journey
(d) Spaceship Skylab: Wings of Discovery

Admission tickets are not required. Members may introduce guests.

Space Study Meeting

Theme **THE VIKING PROGRAMME** by P. J. Parker.

To be held in the Kent Room, Caxton Hall, Caxton Street, London, S.W.1. on **4 April 1975**, 6.30-8.30 p.m.

Admission tickets are not required. Members may introduce guests.

Main Meeting

Theme **EUROPEAN PARTICIPATION IN EARTH RESOURCES (SPACE) PROJECTS**

(To consider National, ESRO/ESA activities in relation to ERTS-1, Skylark, Skylab, ERTS-B, etc.).

To be held in the Architecture Lecture Theatre, University College, Gower Street, London, W.C.1. on **9 April 1975** *(All day).*

Subject areas of interest are as follows:-

(a) Special-to-purpose Space Hardware
(b) Remote Sensing instrumentation – present and future.
(c) Experimental Results
(d) Planned future experiments
(e) Practical possibilities; Economic; International and Legal Aspects.

Papers offered to date are as follows:-

1. *Title to come*, by Dr. D. Bannert
2. Coordination of Remote Sensing Objectives, by S. R. Dauncey
3. Comparison of the Utility of alternative camera, film & filter combinations for Space Photography from the Skylark Earth Resources Rocket, by Dr. J. R. Hardy
4. Attitude Control of Earth Resources Rockets by an RF Interferometric Sensor, by Dr. G. Mayer
5. Application of ERTS-1 Imagery to the Sudan Savanna Project, by C. W. Mitchell
6. Automation of Earth Resources Data Analysis, by O. E. Morgan
7. *Title to come*, by H. Ödegaard
8. Use of Photographic Imagery for Earth Resources Studies, by Dr. E. S. Owen-Jones
9. Computer Analysis of Satellite Imagery, by G. G. Preston and Dr. W. G. Collins
10. Telespazio Facilities for Acquisition & Processing of ERTS Data, by Ing. B. Ratti
11. The Use of ERTS Imagery, by L. P. White

Offers of further papers are invited. Further details are available from the Executive Secretary.

Space Study Meeting

Theme **SATELLITE TRACKING** by Dr. D. G. King-Hele.

To be held in the Kent Room, Caxton Hall, Caxton Street, London, S.W.1. on **17 April 1975**, 6.30-8.00 p.m.

A general review of the radio and optical methods used in satellite tracking, their effectiveness and some of the results achieved.

Admission tickets are not required. Members may introduce guests.

Main Meetings

Papers are invited for presentation at the following Main Meetings:-

(a) **COMPUTERS IN SPACE PROJECTS**
(b) **MATERIALS IN SPACE TECHNOLOGY**
(c) **ADVANCES IN SPACE SCIENCE & TECHNOLOGY**
(d) **COMMUNICATIONS SATELLITES**

PRESENTATION OF PAPERS AT MAIN MEETINGS

(1) Authors are invited to submit details of any papers which they would like to present at forthcoming Main Meetings, either in the UK or at the European Space Symposia which are normally held abroad.

(2) 20 min. is normally allowed for presentation time at meetings, plus further time for discussion. Papers are usually published in the Society's Journal.

(3) Authors who are precluded by reason of distance or other matters from attending personally may also contribute a written MSS, to be published as part of the Proceedings of the Meeting.

(4) Short papers may be presented (up to 10 min. duration) on aspects of particular interest which do not lend themselves to presentation as Main Papers, e.g., Research Reports, Current News, or other Statements of Interest.

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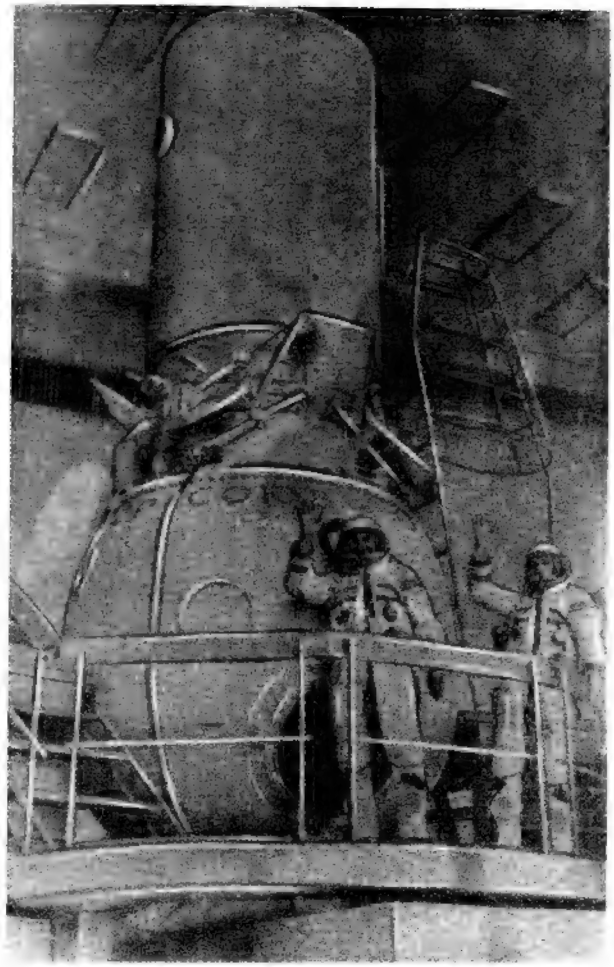

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L. J. Carter, ACIS, FBIS

CONTENTS

COVER

A TEXTBOOK ASTP REHEARSAL. Soviet ASTP back-up crew Anatoly Filipchenko and Nikolai Rukavishnikov, who flew in Soyuz 16, completed tests of the new docking equipment to be used next July in linking up with America's Apollo spacecraft 140 miles (225 km) above the Earth (see *Spaceflight* January 1975 pp. 2-10). They also tested reducing air pressure in their ship, bringing it closer to the low-pressure oxygen atmosphere of Apollo. A retractable ring device, mounted on the nose of Soyuz 16, took the place of Apollo in the docking exercise, making it possible to place the same loads on the Russian craft in simulation of docking. After the experiment the test apparatus was discarded in orbit. *Top*, Soyuz 16 cosmonauts in the ASTP Soyuz trainer at Zvezdnoy Gorodok (Star City); *right*, Soyuz trainer orbital module with ASTP docking equipment and mockup of airlock/docking adapter. *Below*, cosmonauts Rukavishnikov (left) and Filipchenko wearing ASTP insignia.

Novosti Press Agency

T 1

SPACEFLIGHT

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VOLUME 17 NO. 2 FEBRUARY 1975 *Published 15 January 1975*

MILESTONES

November

11 Luna 22 completes 1,778 revolutions of the Moon by 6 p.m. (Moscow time). Station is manoeuvred into new orbit of 171 to 1,437 km at 19°33' to lunar equator; period 3 hr. 12 min. All on-board systems and scientific instruments functioning normally.

15 NASA announces 'New Horizons in Propulsion' programme to investigate possible future developments in propulsion technology under William H. Woodward, director of space propulsion and power, Office of Aeronautics and Space Technology. Study projects include: *Lewis Research Center:* solid, atomic hydrogen rocket propellents: monatomic hydrogen (atoms recombine into molecular hydrogen, theoretical I_s 1,500 sec.); *Jet Propulsion Laboratory Space Sciences Division:* metastable helium maximum I_s 2,800 sec; *Propulsion Division:* use of planetary atmospheres as propellent source for ram-scoop vehicles; mining of planetary crusts; impulsive propulsion (use of detonation to increase I_s of a propulsive working fluid); metastable helium, atomic hydrogen and other activated chemical species; anti-matter.

23 NASA launches 960 lb. (435 kg) British Skynet 2B defence communications satellite by Delta rocket from Kennedy Space Center into preliminary elliptical orbit reaching to geo-stationary altitude prior to orbit circularisation above Indian Ocean two days later (see *Spaceflight*, December 1974, pp. 464-465).

16 First deliberate outward-bound CETI signal transmitted from Earth – to star cluster Messier 13 – to commemorate re-opening of Arecibo, Puerto Rico, National Astronomy and Ionospheric Center following modification to radio-telescope. NAIC director, Dr. Frank Drake, explains: "Coded signal (transmitted at two different frequencies) starts with a simple lesson on how to count and then very carefully describes the chemistry of life on Earth. It tells how complex we are, what our genetic material is. It also tells how advanced we are, by telling in code the structure, growth and brain of a human being." Experiment made possible by resurfacing of 1,000 ft. reflector in conjunction with 450,000 W radio/radar transmitter, which produces a beam so narrow that its energy is increased by a factor of 1,000,000. An inhabitant of Messier 13 – 24,000 years from now – would register the signal "as the clearest and brightest object in the Galaxy" (see page 54).

25 Salyut 3 completes 2,462 revolutions of the Earth by 12 noon (Moscow time). *Novosti* reports that "station has been in controlled flight with permanent Earth orientation for five months ..." (see pages 59-60). Orbit ranges between 247 and 293 km inclined at 51.6 deg to equator; period 89.7 min.

December

2 Soviets launch Soyuz 16 from Tyuratam at 12.40 hr. (Moscow time) with cosmonauts Col. Anatoly Filipchenko (commander) and Nikolai Rukavishnikov (flight engineer). *Novosti* reports that: "Soyuz 16 is identical with spacecraft which will take part in ASTP joint docking experiment with U.S. in July 1975". Flight programme includes testing modified on-board systems, checkout of scientific and technological equipment, and observation and photography of parts of Earth's surface to obtain data "for the solution of economic problems". After a manoeuvre made in the fifth revolution, orbit ranges between 177 and 223 km inclined at 51.8 deg to equator; period 88.4 min.

 В журнале не печатается ряд страниц.

T 2

ASTRONAUTICS IN AMSTERDAM

The 25th I.A.F. Congress reviewed by Louise Parks

Introduction

The 25th I.A.F. Congress was organised by the Nederlandse Verenigung voor Ruimtevaart (NVR) in Amsterdam from 30 September to 5 October 1974, at the modern RAI Congress Centre by the peaceful Beatrix Park.

The Opening

The proceedings were opened by His Royal Highness Prince Bernhard of the Netherlands who outlined the new opportunities which had become available to mankind through its exploration of ocean depths and of space, both these spheres requiring the development of frequently similar new technologies. He remarked that one aspect of space research, namely the remote sensing of Earth resources by satellite, as in the ERTS programme, offered great hope both to the industrial and the developing countries for constructive exploitation of as yet unused resources. Another promising aspect of space exploration was the growing cooperation among various countries, e.g. the Apollo-Soyuz programme, the U.S.-European "Shuttle and Spacelab" project, the European Space Agency, etc.

Finally he mentioned the recent launching of the first Netherlands satellite, and expressed the hope that when the time came a Dutchman would be among the first European astronauts.

After other addresses by the President of the host Society, the President of the IAF and a U.N. representative, Dr. Krafft A. Ehricke, Scientific Adviser of Rockwell International, USA, read his Invited Lecture on New Growth in an Open World, coining the challenging slogan: "Space is not an option, it is an imperative." The youthful idealism with which this rocket scientist of an earlier generation (than most of his audience) put forward his philosophy of mankind being saved from extinction in the future by reaching for the planets and even stars, just as primeaval life on Earth was saved by adapting at a critical stage to an oxygen atmosphere, silenced with its enthusiasm the audience's doubts about feasibility.

Space Stations, Present and Future

The opening session was followed by a Forum on the Congress theme of Space Stations, Present and Future. The speaker on the Soviet side was cosmonaut Colonel V. I. Sevastianov, Doctor of Technical Sciences, a lively, likeable, intelligent and cheerful man, with a gift for putting anybody at his ease. His contribution was largely an outline of Soviet space philosophy. Man's penetration into space "changed the traditional notions of relations between nature and society." Astronautics affected human activities on Earth, and mankind's degree of development determined not only the scientific research programme in space, but also a multiplicity of uses of space research results for the benefit of the community. The main application possibilities at present are: acquisition of qualitatively new data on the natural resources (geological, hydrological, oceanological and biological) on Earth, and the direct utilisation of space systems in the cultural and economic activities of mankind.

The trends in the present use of space facilities are:

1. *Meteorology:* weather forecasting and operational information on the origin and direction of cyclones, tsunami, sand storms, etc.; snow, ice and hydrological reconnaissance and, ultimately, control of weather and climate.

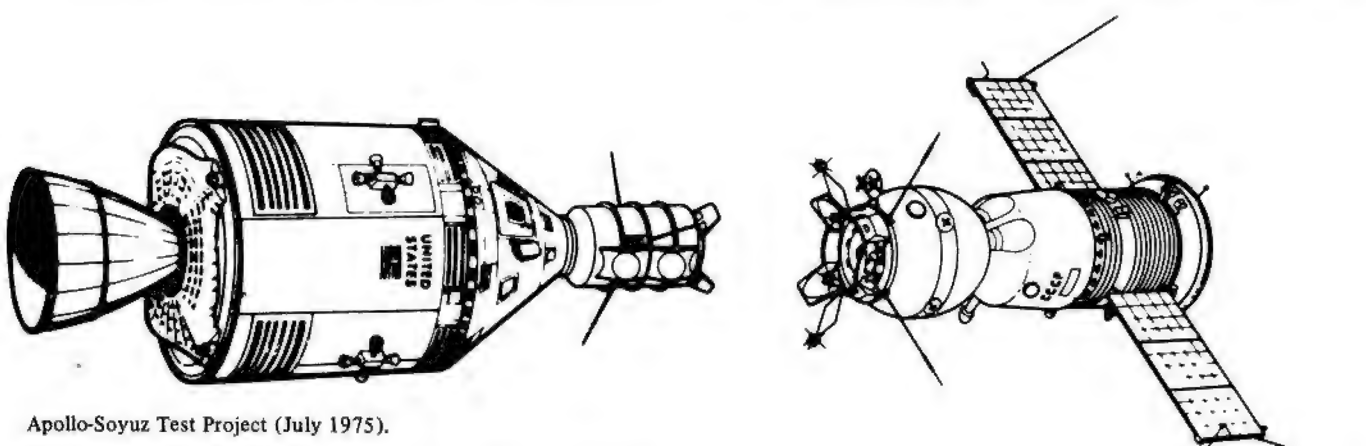
2. *Geodetic and cartographic researches* by remote sensing, radar and, in future, holography for the global mapping of the Earth's surface, and for constant observation of its changes caused by natural forces and man's economic activities.

3. *Investigation of biological resources* and soil conditions in the service of agriculture, forestry, land and desert reclamation, hydraulic engineering and seismology.

ASTP Programme

The subsequent Press Conference with astronaut Brigadier General Thomas P. Stafford and cosmonaut Colonel Aleksey Leonov, U.S. and Soviet commanders of the 1975 Apollo-Soyuz mission, was a jolly but not very informative occasion, with Stafford speaking Russian now and again and Leonov English, this reversal of languages being one of the agreements made by the Apollo-Soyuz teams for their joint flight and training. The main reason for this decision is that people naturally speak fast in their own language and more slowly and clearly in another language, and clear understanding among the team members in their joint work is vital.

A little later in the day this conference was repeated in a more serious vein, not with the Press but with Congress participants as audience. Both Stafford and Leonov related



Apollo-Soyuz Test Project (July 1975).

National Aeronautics and Space Administration

some details of the Apollo-Soyuz joint programme and stressed how well advanced the joint work and understanding were. Although Apollo and Soyuz would each be controlled in space by its own ground station, the two mission control stations would be in continuous touch with each other. The success in the present joint programme suggested that further US-USSR cooperation in space would be useful, and representatives of the Soviet Academy of Sciences were due in Washington next April to discuss the next stage.

Colonel Leonov mentioned that the Soviet experience with the Salyut space station had shown that 84 days was not the limit of man's capability of staying in space, and that Salyut was designed for two cosmonauts staying there for a much longer period. He also confirmed that work was in progress in the USSR on a space shuttle.

It should be noted here that the Russians use the English word "shuttle" occasionally, but only when it applies to a Western space vehicle of that type. For their own design of, and work on, a comparable space vehicle, they use the Russian equivalent of "transport vehicle" or "transport craft" which also embraces the concept of space tug. This term, so deceptively general in English, but used consistently in Soviet technical literature, may be the reason for the comparative ignorance in the West of Soviet published work in this field: a matter of overlooking something that seems to be irrelevant to *space* engineering.

Space Shuttles

A Soviet paper on "The influence of load parameters on the selection of the structure in designing fuel tanks for a (liquid-fuel) transport spacecraft" was later read by Mr. V. Novikov in the Space Transportation Section. After weighing up the relative weight penalty of tank walls reinforced with stringers and the advantages of balancing the stability and strength of thin-walled cylindrical tanks by internal pressure, Mr. Novikov apparently advocated the latter variant but stressed the need for ascertaining accurately the optimum internal pressure of underloaded tanks.

It was unfortunate that another Soviet paper billed for the same session by Academician B. N. Petrov, *et al.*, on shuttle trajectories was not read. Its mention in the programme aroused the audience's expectations.

At the same Space Transportation session Dr. Myron S. Malkin, Director of the Space Shuttle Programme, NASA, USA, read a paper on the "Key Considerations for the Space Shuttle" which analysed all aspects of design and operation of a shuttle. Another U.S. paper was by D. J. Shramo of the NASA Lewis Research Center, Cleveland, Ohio, with colleagues from the General Dynamics Convair Division, San Diego, California, which described the Centaur primary upper stage for exploring the Solar System, and its potential adaptation an upper stage for the space shuttle.

The main sessions of the Congress were quite crowded and so were the two U.S. showings of photograph mosaics of the Mercury surface and of changes in the Venusian cloud cover.

Simultaneous Sessions

The increasing interest and specialisation in the numerous and very varied aspects of space science and engineering, and the popularity of the annual IAF get-together again resulted in 3-5 simultaneous meetings of various sections and symposia throughout the Congress days.

The sections were: Application satellites; Astrodynamics; bioastronautics; Astrionics; Materials and structures; Propulsion; Scientific spacecraft systems; Space transportation systems; Reliability of space systems; Power in space; Unmanned Solar System exploration; Education for space and from space; and Fluid mechanics aspects of space flight. Most of them occupied more time than just one morning or afternoon. There were also: the 7th International Rescue and Safety Symposium; the 3rd International Review Meeting on Communication with Extra-Terrestrial Intelligence (CETI); the 8th International History of Astronautics Symposium; the 4th International Symposium on Cost Reduction in Space Operations; the 17th International Colloquium on the Law of Outer Space, and the 4th I.A.F. International Student Conference, covering a wide variety of subjects.

With such a variety of attractions running parallel it was not surprising that there was a constant to-ing and fro-ing of participants from one conference room to another, for most space enthusiasts and specialists take an interest in more than one narrow subject. Besides, subjects in the sections were inevitably arbitarily categorised and frequently overlapped, e.g. where does one draw the line between "propulsion" and "power in space"? Many Congress participants felt frustrated at being unable to hear some papers of interest to them not only because of sessions running parallel, but also because there were many cancellations and the time tables of the sections were upset. The organisers did their best by issuing programme amendments and chalking notices on a prominently displayed board, in order to counteract this difficulty inherent in organising a large Congress which has to be planned well in advance. There were also some difficulties with the pre-print service. This resulted in pre-prints disappearing within seconds of becoming available in what looked like a scrum of jungle predators.

The Congress languages were English and French, and only one technically inexperienced Russian interpreter was available for the numerous parallel meetings. This was very hard on the many Russians who had difficulties in making themselves understood even when they had prepared English summaries of their papers, as most of them did. They also felt frustrated and aggrieved about their inadequate understanding of the papers of interest to them when they were read in English in a great variety of accents by the English, American, Dutch, German, French, Italian and other speakers.

Excursions

The scientific excursions, connected with the Congress, to the European Space Research and Technology Centre (ESTEC) at Noordwijk, to the Fokker VFW at Schiphol, to the Amsterdam National Aerospace Laboratory (NLR), as well as other establishments, were well attended and of much interest.

The NLR Laboratory, mainly working under contract, was associated with Dutch and European investigators of a number of aerospace problems, the most recent being the testing of the Ariane launcher model in the high speed wind tunnel and the development of the ground operations system for the Astronautical Netherlands Satellite (ANS), as well as the testing of many of the ANS subsystems, e.g. the attitude control logic for radiation susceptibilities in an ingeniously fitted chamber.

The ANS, the first Dutch satellite, was put into orbit on 30 August 1974 from the Western Test Range in California by a Scout rocket. Compacted into its 130 kg total mass are three astrophysical experiments and instruments for

measuring stellar X-ray and UV radiation. Planned observations began on 14 September, in spite of the satellite's considerable deviation, due to a defect in the rocket, from the originally planned near-circular orbit. The chief members of the consortium which developed the ANS were the Fokker VFW and Philips of Eindhoven.

The tour of ESTEC of the European Space Agency (ESA), the amalgamation of ESRO and ELDO, was distinguished not only by its faultless split-second organisation of handling five large groups of visitors simultaneously, but by the indubitable enthusiasm of its multinational, multidisciplinary staff headed by the multilingual nimble-witted Dr. Hammerstroem. Here satellites are designed, developed and tested, but their building is the job for appropriate European firms. From the ESRO scientific satellites ESTEC is now branching out into application satellites, and its major future task is the manned Spacelab project, agreed between ESA and NASA, for which already 240 payload proposals have been received. This means an expansion of ESTEC staff and facilities and, no doubt, an improvement in their computer work. A point which intrigued the English visitors was that the considerable volume of a fuel tank under test is not filled with fuel but with sugar for safety reasons (Why sugar?).

Sections

The first *Application Satellites Section* meeting under the joint chairmanship of an astronaut (R. L. Schweickart, trendily dressed and with fashionably long wavy hair) and a cosmonaut (V. I. Sevastianov) started off with a paper on Skylab by an ex-astronaut Owen K. Garriott. Some other papers on Skylab were read by various speakers at the other three meetings of this section.

A paper on "Spectrophotometric Observations of the Earth from 'Soyuz-13' " by A. A. Buznikov, K. Ya. Kondrat'-yev and others from Leningrad State University was, in the absence of any of the five authors, read by cosmonaut V. I. Sevastianov who was for some time closely associated with this group's research. The main themes of this paper were brightness measurement, such as absolute optical brightness with reference to natural formations on Earth, the effects of the atmosphere on spectral brightness, as well as observations of the atmosphere above the twilight and day horizons of the Earth. A large volume of spectra recorded by 'Soyuz-13' went towards the increase of the number and accuracy of earlier results acquired by Salyut and by earlier Soyuz spacecraft.

Other Application Satellite meetings dealt with data handling systems, mainly for remote sensing, the state of observations from space of Earth resources, and the future of ERTS type satellites and environmental monitoring. The sensitivity, even anxiety , of some Congress participants about ERTS type satellite data collecting on the Earth's surface conditions was not obvious in these meetings, but found expression later in some discussions and papers of the Space Law Colloquium.

An outstanding Soviet paper in the Application Satellites Section "Economic effectiveness of using the space system for remote indication of natural resources" by S. A. Sarkisyan, Dr. econom. sciences, *et al.*, was at the same time a well-reasoned evaluation of the present situation and an optimistic bugle-call for the future benefits accruing from remote sensing of Earth resources as a prelude to their exploitation.

Another paper by the same authors, "Economic aspects of the creation and employment of promising space transport systems," was read in the Symposium on Cost Reduction of Space Operations, one of the many examples of the interests of speakers extending across the limits of subject categorisation.

Another very telling example of how various subjects overlapped the boundaries of the categorised sessions was an informal Forum meeting which showed how costs or cost reductions of space operations could not be separated from the reliability of space systems or the degree of safety of space crews. At that meeting a Dutch suggestion of cost cutting by reducing some pre-flight testing programmes aroused quite heated arguments from the U.S. and Soviet sides. As Prof. Parton of the Moscow Institute of Chemical Machine Building pointed out, no assembly of mechanisms or systems is *identical* with a similar assembly or system. Therefore, one cannot with impunity skimp on tests of the actual spacecraft or probes whose reliability is the very essence of the programme's success.

In the *Astrodynamics Section*, part of which was chaired by Prof. G. N. Duboshin, one of Moscow's prominent experts on celestial mechanics ("a small man, but a great scientist") several papers dealt with the problem of spacecraft stability by spinning, and nearly all papers soared into mathematical altitudes fit only for high-level mathematicians.

One of them was Dr. Kazakova, an attractive young Soviet woman, who read a paper on the secular "Evolution of a satellite's orbit in Hill's problem, taking the planet's oblateness into account" by M. L. Lidov and M. A. Vashkovyak of the Institute of Applied Mathematics, USSR Academy of Sciences, referring mainly to circular orbits.

This was followed by another Soviet paper on the "Effect of short-term variations in atmospheric density on the accuracy of calculating low-altitude orbits of artificial Earth satellites" by P. E. Elyasberg, B. V. Kugayenko (who was present) and M. I. Voiskovskiy of the USSR Institute of Space Research.

Several French papers were concerned with the problem of keeping geostationary satellites in their orbits, while two very lucid papers on re-entry problems came from the University of Michigan, USA.

The U.S. papers on the *Unmanned exploration of the Solar System* were of breathtaking fascination because of the various technical and particularly photographic achievements of the Mariner and Pioneer spacecraft in their exploration of Mercury, Venus, Mars and Jupiter. The forthcoming U.S.-German solar Helios probes promise to be of great interest, too.

The only paper on the East Bloc Interkosmos programme was by V. Guth of Czechoslovakia, a country which specializes in providing scientific instruments for Interkosmos satellites, used in a large number of space physics experiments.

Scientists and technologists of many countries are working on properties and suitability of composite materials for various space applications. Many of these materials have already been used in the aircraft industry, but specifications for space uses are more stringent and new variants have to be developed. In the *Materials and Structures Section* the Dutch Fokker Aircraft Corporation's Space Division was reported as having developed sandwich sheets with a composite core and a carbon fibre face for the ESTEC test satellite (M. P. Nieuwenhuizen).

The detailed and well-illustrated report on the optical requirements for the window mounted in Skylab's multiple docking adapter and used for photography with the S.190 camera was another very instructive paper, particularly in

regard to the meticulous testing of stresses, and ingenious adaptations to differing thermal and mechanical stresses in parts of the 43 x 59 cm window.

One of the interesting Soviet papers (on the design of pressure vessels) was unfortunately withdrawn, but a paper on a study of the carrying capacity and deformation of multi-functional coatings of composite materials in simulated space conditions, by G. S. Pisarenko, E. S. Umanskiy and E. A. Eskin of the Institute for the Problems of Strength of the Ukrainian Academy of Sciences, described their special test installations.

Solar Furnace

One of the most interesting developments in Soviet space technology is the systematic research on the processing of materials under weightless conditions. In a paper entitled, "Some features of the formation of melts in weightlessness with radiant heating, and prospects of using solar energy for space engineering", 10 scientists and engineers* of the Ukrainian Academy of Sciences reported on a series of experiments on contact-free heating in a controlled atmosphere or in vacuum, and in the absence of pressure and force fields. This made possible the study of materials "in a fused state regardless of their high-temperature strength and electromagnetic properties".

Earlier investigations† of the feasibility of using concentrated solar energy for industrial purposes, particularly for welding, soldering and the heat treatment of certain alloys, led the research team to studies of material fusing by means of concentrated radiant energy under simulated space conditions in an aircraft laboratory. The main objectives were to investigate:

1. The behaviour of a metal melt during its formation and solidification on plates of various materials and thickness;
2. Formation of welds on plates of stainless alloys;
3. Wetting metals by solders and preparation of soldered combinations; and
4. Free formation of spheres of various alloys in non-wettable crucibles of refractory compounds.

The studies were made in conjunction with an apparatus which incorporated a so-called "concentrated solar energy imitator (CSEI)". The device (Fig. 1), mounted on a structure of welded tubing, includes a vacuum chamber in which a controlled source of radiation is beamed to impinge on test samples. The stand also supports vacuum and diffusion pumps which can be changed for different experiments.

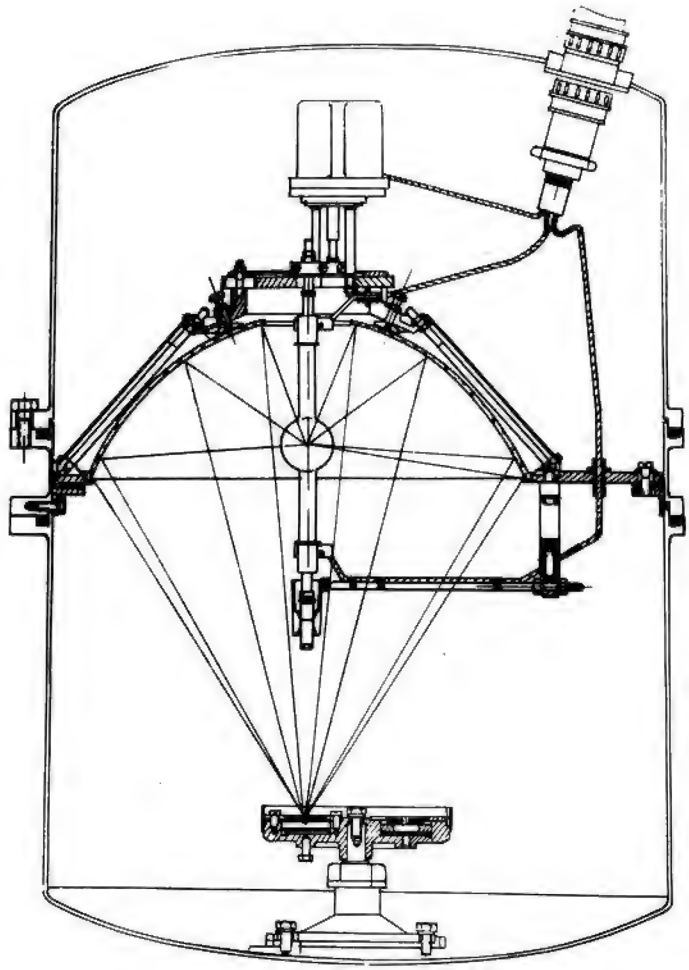


Fig. 1. Sectional drawing of the Concentrated Solar Energy Imitator (CSEI).

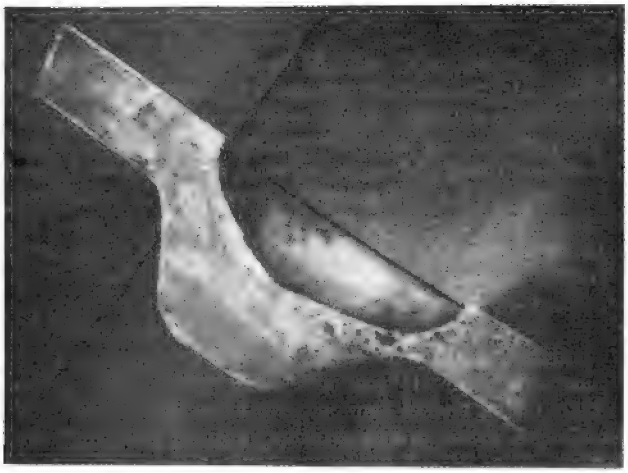
Ukrainian Academy of Sciences

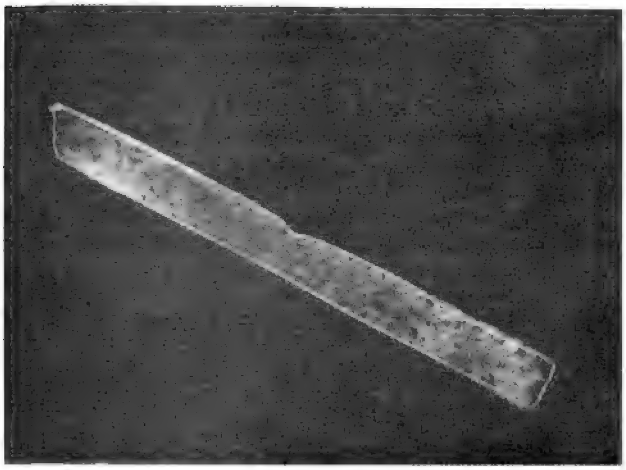
During the flight experiment, for example, a vacuum pump assembly allowed the chamber to be evacuated to 10^{-5} mm Hg. There was also provision for filling the chamber with a neutral or any controlled medium. Recording and control devices were embodied to allow the whole process to be studied at leisure.

The concentrated solar energy imitator (CSEI) is a framework construction of light alloy, upon which is mounted the aluminised ellipsoid dish of the 350 mm reflector. The first focus of the reflector has an xenon high-pressure lamp of 1 kv. A special device allows the lamp to be moved 10 mm along its axis and be fixed accurately in any intermediate position. This small amount of movement allows control of the density of radiation falling on the sample at the second focus of the concentrator. This allows the incident radiation flux to be changed by a factor of 2.5. The xenon lamp works at two levels: operational and nominal. At nominal, the

* *I. N. Frantsevich; V. S. Dvernyakov; V. F. Lapchinsky; I. Ye. Kasich-Pilipenko; A. A. Sharin; V. V. Pasichny; A. A. Zagrebelny; I. G. Lyubomudrov; V. N. Kurilo, and R. V. Minakova.*

† 1. *V. S. Dvernyakov, and V. V. Pasichny, "Determination of the parameters of a special solar energy installation designed for the study of materials and refractory alloys". Doprovidy AN UKR SSR, 5, 1966, (Proceedings of the Ukrainian Acad. Sci.).*
2. *I. N. Frantsevich, V. S. Dvernyakov, V. V. Pasichny, et al. "Study of the feasibility of using radiant solar energy for welding and soldering in space", 23rd IAF Congress, Vienna 1972.*





Figs. 2 and 3, microstructure of formation of a tin melt (top) and under weightlessness (bottom).

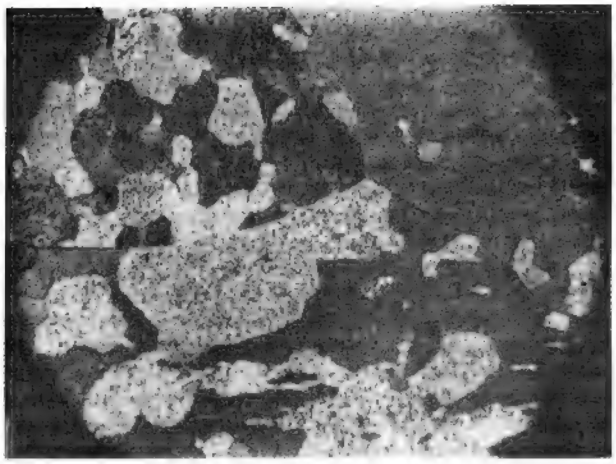


Fig. 4. Microstructure of tin solidified under weightless conditions.

power of radiant flux on a light spot 5 mm in diameter is 140 W, while the average density of the radiant flux is near 700 W/cm^2.

The programme involved first the development of an experimental technology under ground conditions. Then the experiment was transferred to the aircraft laboratory so that tests could be made alternatively under gravitational and weightless conditions. In some cases the experiment was repeated on the ground after the flight.

Comparative studies have been made of the influence of gravitational field forces and of weightlessness on the macro-and-micro-structure of primary solidification of pure metals (Sn,Cu, Ag) and alloys (Cu-Ag, Te-C) which are formed by remelting, welding and soldering.

These studies showed that with 'fixed baths' the gravitational forces lead to visible sagging of the melt. However, under weightless conditions, the melt is held in the initial state by surface tension and interatomic forces. Figs. 2 and 3 show a small cavity that was restored to its initial state with the transition to weightlessness.

The structure of solidification is determined, other things being equal, by the amount and distribution of contaminants and by their interaction with dislocations. When tin is solidified it is seen in the formation of two substructures, cellular and band, with coincident boundaries (Fig. 4).

The coincidence of boundaries is due either to the fact that the elastic energy of dislocation structures forming a boundary between bands can be minimized by the contribution of contaminant cells in walls, or to the coalescence of a cell on a contaminant wall.

The structural features formed in weightless and gravity conditions differ in accordance with the distribution of contaminants,more uniform in the first case,and the associated size reduction.

In the solidification of commercially pure copper the contaminant distribution determines cell sizes and the structure of their boundaries. Micro-structures of copper solidified in the gravitational field and in weightlessness are seen in Figs. 5 and 6 respectively.

The researches suggest the possibility of more uniform distribution of short-grained structures under weightlessness becoming the basis of space technology. What is attractive, the Russians say, is the possibility of using an inexhaustible source of energy, the Sun, for industrial purposes. Earlier they have shown the possibility of carrying out much exploratory and technical work at fixed ground-based solar power plants. But no existing plant satisfies the requirements for use in space. Space solar plants must be as small and as lightweight as possible, have facilities for remote observation and automatic control of the processes of heating, and the manipulation and changing of specimens. There must also be a system of Sun orientation. In addition, the plant's design must meet the requirement of performing all its operations in ground conditions.

The research team has now designed and built a prototype solar plant to these basic specifications (Fig. 7). It is compact, and its main heating unit can be mounted on a spacecraft by means of a special attachment. Alternatively, it can be used in Earth conditions in a vacuum chamber. The device has multipositional mechanisms with which a series of experiments can be performed without unsealing the vacuum sys-

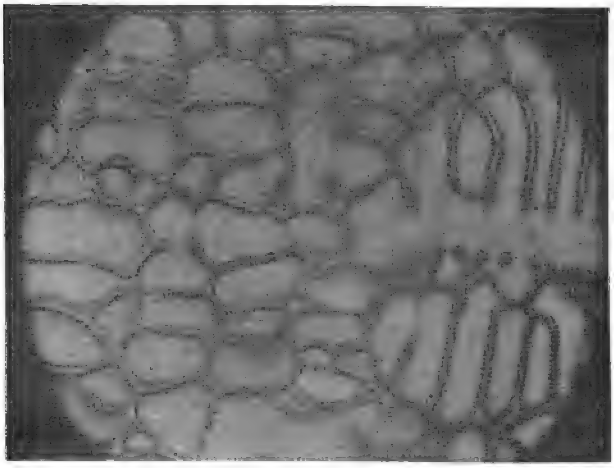


Fig. 5. Microstructure of crystallized copper in a gravitational field.

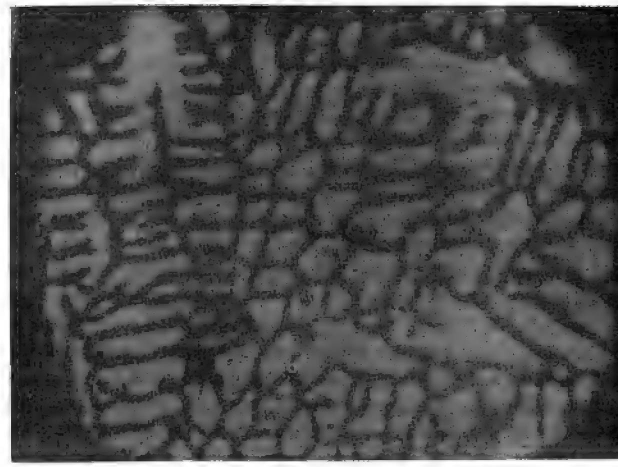


Fig. 6. Microstructure of crystallized copper under weightlessness.

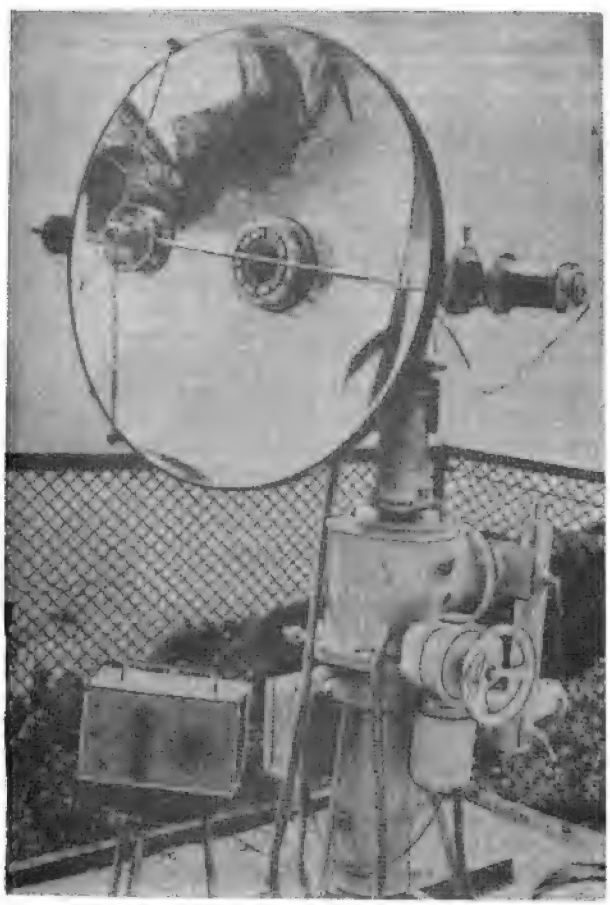


Fig. 7. Small solar power plant for carrying out technological processes in space.

tem. A specially designed, programmed optical system directs the required quantity of radiant energy to the surface to be heated.

The optical system – a modernised Mersen design – allows a parallel flow of radiant energy to be reflected from a paraboloid, focussed by means of a lens at the pinnacle of the main concentrator. This makes possible technical operations in space on large objects without being impeded by the effects of shading on focal power. Observation of processes inside the chamber is by a television system using the main optical system.

Ground based estimates of the energy parameters of the solar plant were made by the calorimetric method with a main concentrator beam of 5 mm diameter. With normal solar radiation of 0.07 W/cm^2, the radiant energy at the focal lens point was found to be 418 W and the value of incident energy 1240 W. The mean density of energy in the area of a 7 mm diameter focal point is 870 W/cm^2.

Extrapolation for values under space conditions suggest that solar radiation of 0.145 W/cm^2 will have a radiation density at the lens focus of 1900 W/cm^2. Such a density, say the research team, makes possible a reduction in size of the solar energy concentrators for space use.

Propulsion

Some new industrial processes were mentioned as developed for the Helios solar probe which, being completely coated with dielectric material, is to receive a "conductive coating" for electrostatic cleanliness (P. Stämpfl and W. Winkler of the Federal German Society for Space Research). Other interesting papers included the French vibration testing of structures report and the cryogenics of their SRET-2 satellite.

In the *Propulsion Section* Yu. S. Ryazantsev of the Institute for Problems of Mechanics, USSR Academy of Sciences, in his paper on the "Calculation of acoustic admittance at the burning surface of a solid propellant," described a calculation method based on experimental data of a steady burning rate and steady surface temperature expressed as functions of pressure and intial temperature from which the appropriate unsteady burning laws are deducted in accordance with a Soviet

theory; heat conduction in the condensed phase is assumed to be the only delay process.

A number of papers including Soviet ones were withdrawn in this section, too, but there was C. A. Zimmerman's (Lockheed Missiles and Space Company, California) "Solid rocket motors for the Space Shuttle" and K. Thom, *et al.* (NASA) on "Potentials of plasmas for space power and propulsion."

The papers in the *Fluid Mechanics Section* were very specialised from whatever country they came (see President Luigi G. Napolitano's "Numerical experiments in the aerodynamics analysis for the Space Shuttle") and full of mathematical abstractions. This presented no difficulties to the Soviet woman mathematician from Leningrad State University who read a paper on "Equations of relaxation aerodynamics for reactive gas mixtures." She was followed by P. Th. L. M. van Woerkom of the Dutch National Aerospace Laboratory who acquainted the audience with details of work done there on "Generalised models for the study of the interaction between spacecraft and atmosphere."

Bio-astronautics

The *Bio-astronautics Section* was squeezed into two sessions on the same day. Some of the interesting Soviet papers were not read in spite of the presence of two Soviet biologists with adequate knowledge of English and in possession of English texts of the Soviet papers. Both of them, E. Ya. Shepelev and V. N. Belyanin, the latter from the Institute of Physics of the Siberian Department of the USSR Academy of Sciences in Krasnoyarsk, were concerned with chlorella research. The paper by I. A. Terskov, V. N. Belyanin, *et al.* was on the productivity of *Chlorella vulgaris* in conditions of photoperiodicity as compared with continuous illumination.

The paper on the study of a bioregenerative life support system based on chlorella photosynthetic activity combined with the action of micro-organisms, by E. Ya. Shepelev *et al.*, related some of the many experiments aimed at establishing a gas exchange equilibrium between man and algae, a problem which has not yet been solved satisfactorily as a whole. In the experiments under examination the gas exchange was balanced in regard to oxygen, but the CO_2 absorbed was only about 3% of the CO_2 volume produced by the one human subject of the main 29-day experiment. The system's air volume was $4.5m^3$, the initial water volume was 60ℓ. Micro-organisms effected urine decomposition; water evaporated by man and resulting from drying solid wastes also went back into the photosynthetic reactor. The algae culture volume was 30ℓ at 7-8 g/ℓ suspension density. The collected and purified water vapour condensate was used for drinking and food preparation. The system achieved 100% oxygen, 90% water and 8% food recovery (some dried chlorella mass was introduced into the subject's diet) in 15 oxygen and 1.5 water regeneration cycles during the experimental month. The advantage of this experimental system is its continuous functioning and relatively low control requirements.

The paper by O. G. Gazenko, N. N. Gurovsky *et al.*, on the medical investigations during the flights of Soyuz 12, Soyuz 13 and Soyuz 14 spacecraft and the Salyut 3 orbital station dealt mainly, and in great detail, with the measures and equipment used in these spacecraft to counteract the effects of weightlessness during the space flight and the after effects on the crew's return. These measures were partly prolonged exercises and partly full and partial space suits and gravity-simulating fittings.

According to the detailed post-flight medical investigations the combination of these measures went a long way towards counteracting the deleterious effects observed after earlier long-term flights in regard to readjustment to Earth gravity.

The Soviet findings on initial adaptation symptoms to weightlessness (nausea, vestibular difficulties, disorientation) were similar to those examined by American scientists (see papers by A. Graybiel and E. F. Miller *et al.*, on Skylab astronauts, and other papers at the Congress), but there was one odd feature: when the Soyuz cosmonauts entered the much more spacious Salyut space station the sense of disorientation recurred for a brief period, but they escaped vestibular symptoms by deliberately slowing down their movements, particularly head movements.

Some other Soviet papers dealt with ground-based experiments on the effect of low concentrations of CO on a human organism in a closed chamber, and on effects of experimental diets of synthetic proteins with mineral supplements.

A paper on "Life support systems for animals in the specialised biological Earth satellite Cosmos 605" would have created much interest had it been read. Prepared by B. A. Adamovich *et al.*, of the Institute of Biomedical Problems, Moscow, it dealt with biological research in unmanned satellites which require wholly automatic life support systems for animals and other biological objects. This requirement applied to earlier Soviet and U.S. biosatellites and it certainly applied to Cosmos 605 in which no fewer than 45 Wistar albino rats were housed in individual cylindrical capsules arranged in nine groups.

Each capsule (Fig. 8) was provided with air of comfortable temperature and humidity, "day-and-night cycle" illumination, food and water containers, means of removing uneaten food, excrement, hair fragments and harmful gases, as well as with means of recording spontaneous movements and their extent, and with means for sealing off any capsule if no movement was recorded from it for 24-hours.

In addition to the groups of individual rat capsules there were integrated units for air supply, for the regeneration of the recycled atmosphere, for gas analysis which exercised automatic control of the air regeneration unit, for thermal and humidity regulation and the storage of condensate (up to more than 20 litres) as well as a control and switching unit controlling the electricity supply, radiotelemetry, etc., in accordance with programmed commands.

The walls of each capsule served as a circuit of the HF generator providing information on the animal's movements. Each movement produced a signal which was amplified and analysed, and all signals were summarised at two-hourly intervals and recorded in this condensed form in the memory store for subsequent telemetric transmission during the periods of communication with the ground. The two-hour information cycle applied also to the automatic monitoring system of each animal's functional state.

Waste was removed by air jets from the ventilation system through a grille in the capsule floor. Food, 40g in paste form, was supplied to each closed feeding container at 6-hourly intervals. Then the containers opened and the animals had access to the food for six hours. Telemetry data from the special zero-gravity food pumps provided information on the individual animal's food consumption, as well as on the

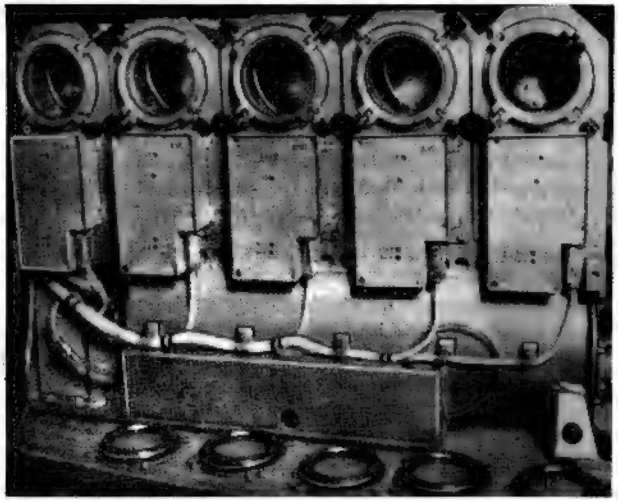


Fig. 8a. No fewer than 45 albino rats were carried in the Soviet bio-satellite Cosmos 605. Picture shows five of the cylindrical animal containers which were arranged in nine groups.

Fig. 8b. System for maintaining the health of experimental animals and monitoring their state aboard the bio-satellite Cosmos 605. *Left*, oxygen bottles, pumps and pressure regulators; *below*, connecting unit, monitoring unit and processing and converter unit; *right*, individual life-support compartments include food and drink dispensers and facilities for waste collection.

Institute of Biomedical Problems, Moscow

entire functioning of the food supply system. Water was also supplied every six hours to reservoirs.

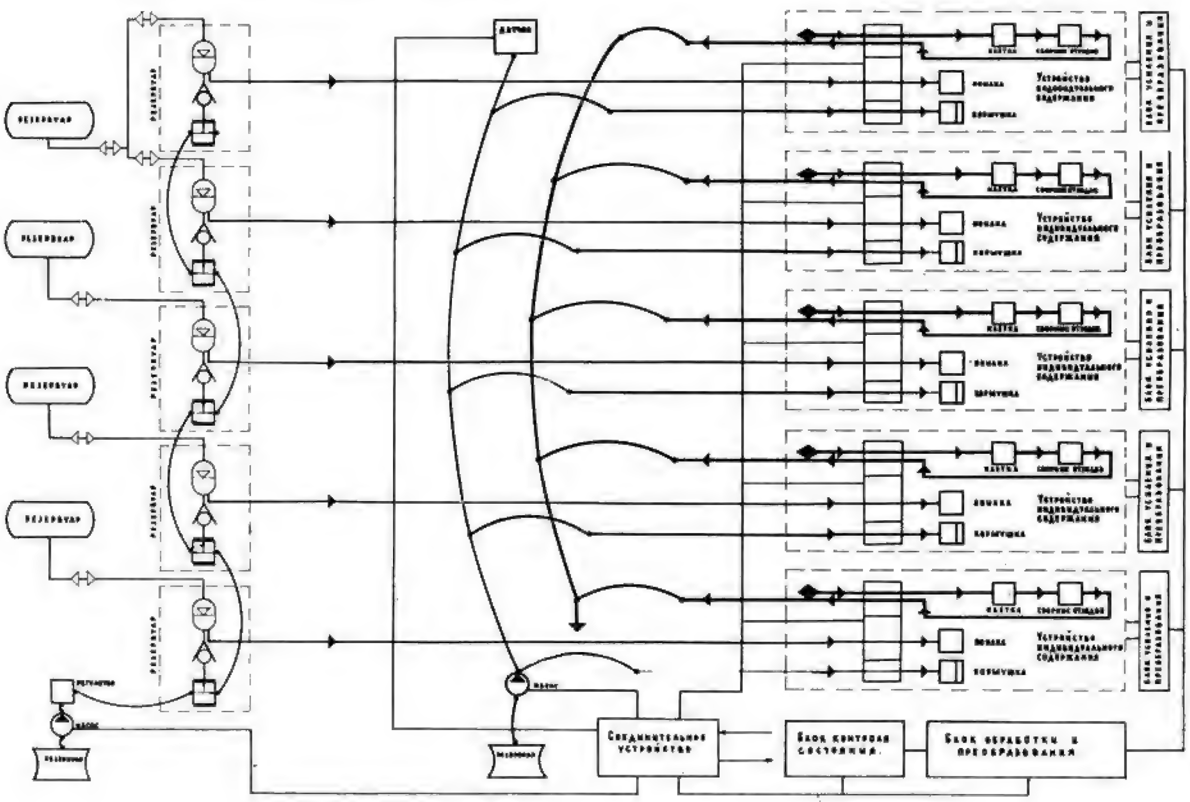
The air regeneration system was based on filters and reliable, light-weight cartridges of chemical absorbents and oxygen-containing substances were released into the system alternately or as the situation required. The ventilator which was the operative unit for this system was duplicated, the back-up ventilator taking the function over automatically in the event of malfunction of the main ventilator.

Oxygen pressure was maintained at 150-210 mm Hg and the CO_2 content was not more than 2% of volume. The system's operation was telemetered, and could, if necessary, be modified by commands from the ground. The system was controlled and metered by a small magnetic-mechanical gas analyser measuring the oxygen content of the atmosphere. The humidity sensor was of the lithium chloride type.

Telemetered data on nearly 150 parameters were speedily processed on the ground from where control could be exercised in virtually any case of failure in the automatic on-board equipment.

According to the designers, the results of the Cosmos 605 experiment proved the correctness of the selection of the individual subsystems and the design of the life support system as a whole. It is suitable for use in animal experiments in prolonged space flights limited only by the volume of the necessary food and other supplies. [The Russians have since launched another biosatellite Cosmos 690. –Ed.]

A paper which aroused a lengthy discussion was that by W. J. Oosterveld and A. J. Greven (University of Amsterdam) – with film – on the flying behaviour of pigeons in weightlessness during parabolic flight. Although more than two



types of handicaps were imposed on the pigeons, there were two distinct modes of attempted flying. The unhandicapped pigeons flew upside down, while pigeons with hoods on (visual deprivation) spread their wings for flight but could do nothing but tumble backwards in inside loops. The experimenters attempted to draw conclusions from the birds behaviour, allegedly indicating that the birds, in weightlessness, experience (vestibular-induced) illusions similar to those experienced by astronauts, but more experimentation is essential before such conclusions can be drawn.

Space Law

The 17th International Colloquium on the Law of Outer Space took up four half-day sessions, keeping to its time table in an almost model manner under the chairmanship of Dr. (Mrs) I. H. Ph. Diederiks Verschoor. The meetings dealt with Direct Broadcasting by satellites, Prospects of Space Law, International Organisations, etc. Some of the papers and discussions betrayed uneasiness about the legal aspects of remote sensing by satellites, with differences of opinion on "ordinary" and "legal" meanings of certain words and phrases.

Not only did the Legal meetings boast of greater female attendance than the technical sessions, but the Ladies Committee of the Congress managed to slip in a talk on Space Law as a prelude to a lively sherry party for the wives of Congress participants.

The highlight of the social life of Congress participants was the reception by the Mayor of Amsterdam at the Rijksmuseum where everybody was free to wander about among the Rembrants, Vermeers and similar treasures.

Communication with Extraterrestrial Intelligence (CETI)

The 3rd International Review Meeting of Communication with Extraterrestrial Intelligence (CETI) also took place during the Congress, the Proceedings of which will be published by the International Academy of Astronautics.

Professor R. Pesek of the Czechoslovak Academy of Sciences, the Chairman of the Meeting, summed up CETI activities over the past three years:

These involved not only the study of all the controversial theories of the origin of the Universe and all its parts, the origin of life on Earth and the possibility of life elsewhere, particularly intelligent life, but also the concrete engineering "know-how" of developing and manufacturing equipment likely to enable mankind to seek other possibly existing intelligent life forms in the Universe.

As it now seems clear that there is no intelligent life on the other planets of our Solar System, one of the present research trends embraces astrometric, spectrometric and photometric methods for detecting planets around other stars. The resolution of the Large Space Telescope, when in orbit, should be capable of detecting stellar planets up to 30 light years away. There is also a suggestion that starless ("stray") planets, may exist.

Prof. Pesek referred to frequently-controversial theories about the origin of life on Earth, strangely enough regarding Monod's chance theory as "pessimistic", while not applying a similar term to F. Crick's and L. Orgel's "panspermic" hypothesis.

Regarding the evolution of intelligence and technical civilisation on Earth, he apparently concluded that not much has been added to the subject since it had been discussed in 1971 at Byurakan.

Prof. Pesek reviewed various proposed techniques of contact, the extent of programmes to search for signals from space and the deciphering of possible messages. There were three main research groups at:-

1. Cornell University radio telescope, Arecibo, Puerto Rico.
2. Radiophysics Institute, Gorky, USSR, and its subsidary stations in various areas of the USSR and on the Soviet research ship *Akademik Kurchatov*.
3. A group of 21 young scientists headed by Dr. N. Kardashov, an astrophysicist from the Institute of Space Research, USSR Academy of Sciences, and D. L. Gindilis, a radio astronomer of the Shternberg State Institute of Astronomy, Moscow, who in simultaneous tests, used portable equipment in remote areas of the USSR.

Results so far have been inconclusive. Perhaps the two Canadian Universities planning a systematic search for space signals with a 50 metre radio telescope will have better luck!

Because the believers in CETI think that the possibility of contact "increases almost yearly," they are naturally concerned with the impact which the discovery of alien civilisations might have on mankind, and this has given rise to sociological philosophising.

Some scientists are merely concerned with the means of finding signs of life on planets. A paper by B. I. Verkin, *et al.*, of the Physical-Technical Institute of Low Temperatures in Kharkov, Ukraine, proposed automatic detection methods of tryptophan and pyridine nucleotide in the soil at different depths by means of luminescience techniques which had been tested in an almost lifeless part of the Kara-Kum Desert. The technique aims at the detection not of biological but possibly biogenic items.

To conclude, Prof. Pesek expressed the opinion that the CETI programme should come under the auspices of a world organisation, e.g. the United Nations, though, for the time being, the non-governmental International Academy of Astronautics should continue to encourage such research as part of its programme.

The 1976 Congress of the International Astronautical Federation will be held in Los Angeles, California, U.S.A. Portugal the provisional venue for 1975 – was unconfirmed at the time of writing.

OPENING THE FAR FRONTIER

By Kenneth W. Gatland and Anthony T. Lawton

A review of the giant astronomical instruments being prepared in the Soviet Union and the United States for a new era of optical and radio observations.

Introduction

The Soviet 6-metre Reflector

In the heights of the Northern Caucasus not far from the village of Zelenchukskaya, east of the Black Sea, Soviet astronomers and engineers are putting the final touches to the world's largest optical telescope. The 6-metre (236 in.) reflector of the Special Astrophysical Observatory, which is under the direction of Professor I. M. Kopylov, will have a staff of about 40 professional astronomers [1].

Many features of the 840 tonne instrument are unique. The primary mirror, assembled in Leningrad, was ground from a mirror blank nearly 20 ft. (6.09 m) in diameter and weighing some 42 tonnes; made of low-expansion borosilicate glass (similar to 'Pyrex') it is about 65 cm (26.6 in.) thick. Figuring of the mirror is still in progress at the site. It is planned to achieve an image disc of 0.3 to 0.4 sec of arc (Hartmann constant 0.15 or 0.20).

Figuring is the term applied to the finishing, lapping and polishing of the optical surfaces. By doing the final work on site, the mounting and settling errors of the supporting structure can be minimised or eliminated. Furthermore, the ambient air temperature must be controlled to fine limits and the polishing carried out very slowly to minimise frictional heating. Even so, the optical surface must be allowed to cool before measurements are taken.

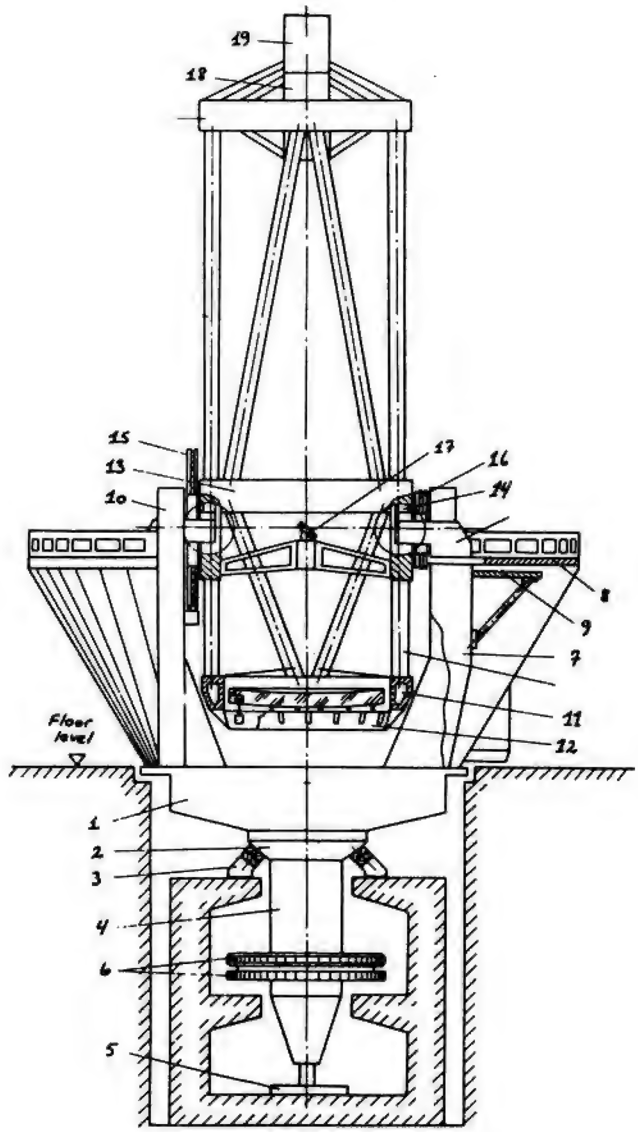
The mounting and steering of such a massive mirror further taxes technical ingenuity. An equatorial mount was considered and rejected on the grounds of weight, complexity and cost. The 6-metre telescope is therefore altitude/azimuth mounted and employs a computer system to convert the normal Right Ascension and Declination co-ordinated into suitable altazimuth control signals.

In addition, the mirror is compensated for the distortion produced by its own weight as it is steered in elevation. The compensation is provided by minute adjustment of the rear of the mirror *via* computer-controlled screwjacks.

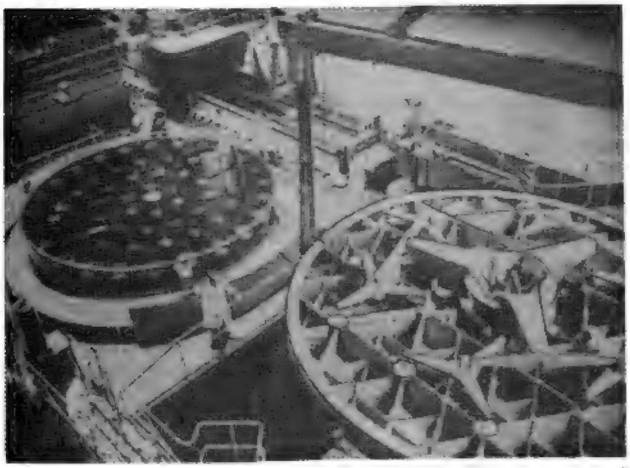
The M.222, one of the most up-to-date computers in the Soviet Union, has a 16,000-bit memory of which 4,000 bits are used in the operating system [1]. The memory capacity is being doubled to permit on-line data reduction of the telescope's observations.

Soviet astronomers have big plans for observing programmes, including the birth of galaxies in clusters of existing galaxies, the mass exchange in binary systems of stars, and light variations in short period variables.

Above, the Zelenchuk Astrophysical Observatory on Mount Semirodniki in the Northern Caucasus which today contains the world's biggest – 236 in. – optical telescope.



Right, principal features of the Soviet 236 in. reflector: Key: 1. Base platform (100 tonnes); 2. Ring support; 3. Oil pads; 4. Vertical mount; 5. Adjustment device; 6. Spur and worm gears; 7. Vertical pier; 8. Observation platform; 9. Structure; 10. Vertical pier; 11. Primary mirror support; 12. Cell of primary mirror; 13. Support structure; 14. Alt-axis oil pads; 15. Worm gear; 16. Cable reel; 17. Tetiary mirror; 18. Cell of secondary mirror; 19. Prime focus observer's cage. The telescope is now under trial, and some observations of deep space have already been carried out. It will be able to investigate objects at distances exceeding 10,000 million light years.



Mirror of the 236 in. telescope during manufacture by an optical works in Leningrad.

Novosti Press Agency

The RATAN 600

The radio companion of this optical giant can be seen from the approach road to the Zelenchukskaya Observatory in the valley. Named RATAN (Radio Astronomical Telescope of the Academy of Sciences) it is to be used for radio-astronomy, radio-physical research, radio-location of space objects and similar applied tasks. It is currently the world's largest radio-telescope with an aperture of 576 metres (1,889 ft.) with a variable profile phased array working over the range of 4 mm to 21 cm [2]. The design was worked out in conjunction with experiments made with the Large Pulkovo radio-telescope.

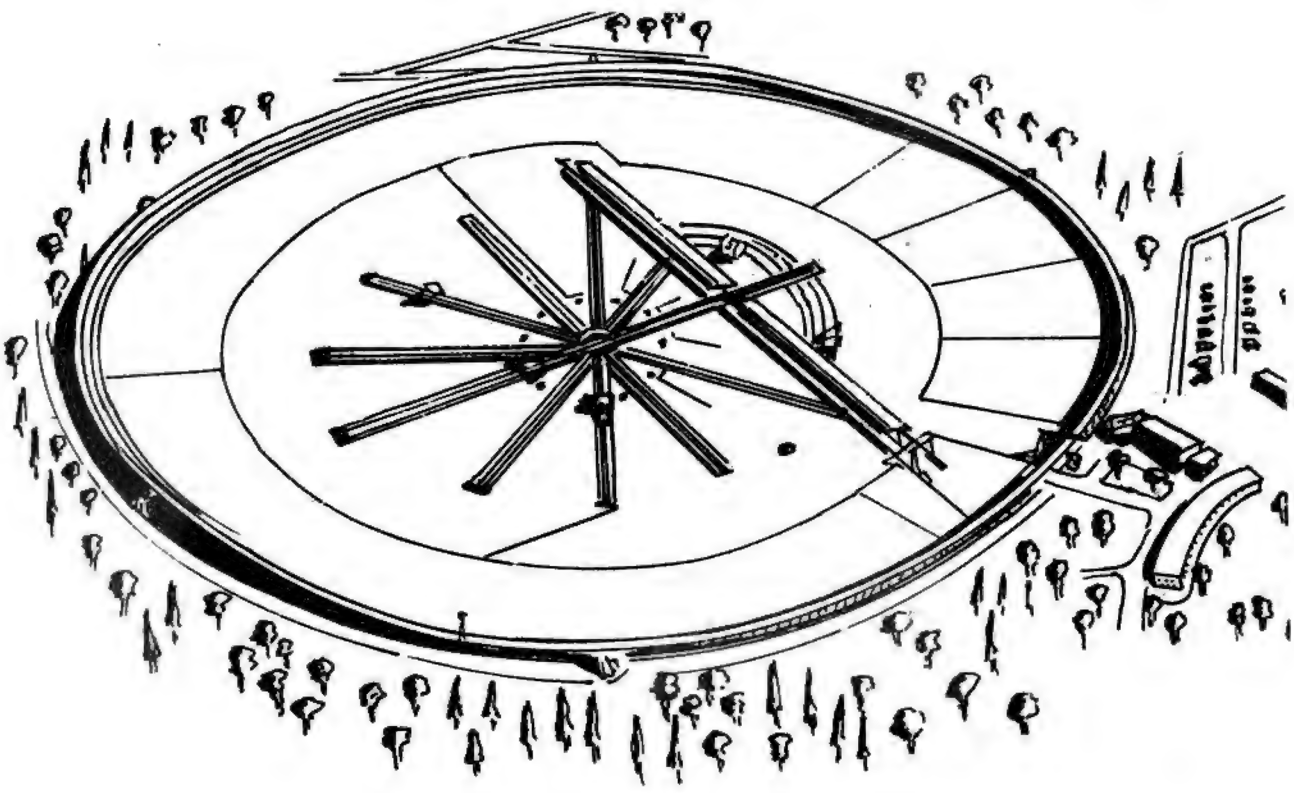
The huge instrument consists of 900 aluminium parabolic panels mounted in a circle 3/8ths of a mile across. Built on a site of 45 hectares on the southern side of the Zelenchukskaya settlement, the location was selected from 27 possible sites in different parts of the U.S.S.R. Special quarters for astronomers using both the 6-metre reflector and the RATAN-600 have been built at Zelenchukskaya. Nearby towns are Mineralniya Vody and Thilisi which have rail links with Moscow and Leningrad *via* Baku.

When operational each of the hundreds of parabolic panels will be adjustable in azimuth, elevation and disposition such as to maintain correct phasing under the control of a computer, with the operator merely indicating the position in the sky to be observed.

The huge radio-telescope can be operated either as four independent sections or as a single unit. It is probable that its future use envisages maintaining simultaneous communications with various Soviet space probes operating in remote parts of the Solar System.

The stated object of this massive instrument is to "catch faint signals from distant stars and nebulae and to maintain long-range space communications." Astronomical objects for study include radio-galaxies, extra-galactic nebulae and separate clouds of neutral and ionised hydrogen and hydroxyl. Of special importance is the investigation of fluctuations in galactic background radio emissions with emphasis on items of small angular diameter.

There is, of course, great interest in observing radio emissions from individual stars. In solar observations it



should be possible to study the fine structure of the corona, chromosphere and also the structure of active regions and other small details (granules).

The RATAN-600 director, Professor Y. N. Parijskii, says it should also be possible to observe all the planets of the Solar System, large satellites and a number of minor planets. Previously, Soviet radio-astronomers have reflected radio signals from the nearer planets using their most powerful directional dish at Serpukhov, located some 50 miles due south of Moscow. Signals were transmitted to and reflected from Venus as early as November 1962.

RATAN-600: Principal Characteristics

Antenna type	Variable profile, computer controlled; equipped with a flat plane secondary reflector for quickening the survey and observations requiring long exposure.
Wavelength range	0.4-21 cm.
Diameter	576 metres (1,889 ft.).
Maximum height	7.4 metres (24.3 ft.).
Effective area (for a single observation)	1000 metres^2 (10764 ft^2).
Horizontal beam width	$\sim$5" at $\lambda = 0.8$ cm.
Effective antenna temperature	30°K at 21 cm rising to 50°K at shorter wavelengths.

Arecibo Refit

Meanwhile, America's 1,000 ft. (305 metre) radio-telescope which nestles amongst the mountains of Western Puerto Rico at Arecibo, has just been modified at a cost of $8,000,000 ready for an important new programme of observations [3]. Operated by Cornell University for the National Science Foundation, the huge static dish has been re-surfaced and re-figured for greater accuracy at shorter wavelengths.

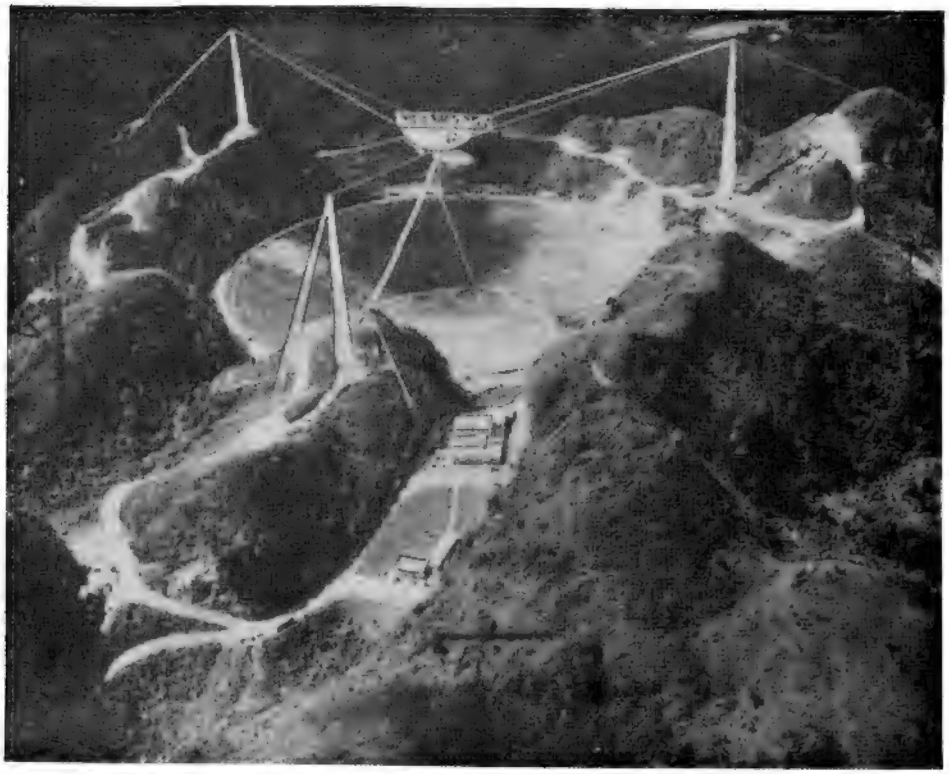
Originally the reflector consisted of a gigantic parabola of steel net set in a reworked natural bowl formed by mountain peaks. The fixed dish obtains its directional capability by moving the receiving aerial which is strung on cables from three tall pylons above the paraboloid.

The panels which replace the steel net are perforated both to allow for rain drainage and to permit sunlight to reach underlying vegetation and so prevent erosion of the natural bowl in the ground.

The more accurately formed paraboloid allows the telescope to work at shorter wavelengths which, of course, means higher resolution.

The receiver has also been modified and special attention paid to achieving a very low antenna temperature*. Figures of 20°K to 30°K are believed attainable. This offsets the smaller aperture of the U.S. instrument in terms of sensitivity

* *Antenna temperature is a measure of noise in the front end of the receiver. The lower the temperature the lower the noise factor; e.g. all other things being equal an antenna with a temperature of 20°K will have twice the sensitivity of an antenna of 40°K. In terms of 'signal grasping' capability it will reach out half as far again.*



Right, radio telescope of the National Astronomy and Ionospheric Center near Arecibo, Puerto Rico. After being modified the huge instrument was re-opened in November 1974 in a ceremony marked by the transmission of a CETI message to the star cluster Messier 13 (see page 54).

United States Information Service

Left, the Soviet RATAN 600 which may also be used in CETI experiments. This massive instrument employs a Kraus radio telescope layout which is more economical to construct, and allows a high degree of steerability with very little sacrifice in terms of aperture collecting efficiency when compared to the more conventional paraboloid.

(when compared with the Russian instrument), and in many respects Arecibo and RATAN are almost indentical. All the range of astronomical observations specified for RATAN-600 are possible and one of the first tasks for Arecibo will be the radar mapping of Venus when that planet is in favourable opposition in 1975.

It remains to be seen whether the Russian instrument will be ready at this time for the 1975 Venus launch window is open in the May-June period. There have been suggestions that the Soviet Union may be preparing a new-generation Proton-launched spacecraft for placing in orbit around Venus. If power demands can be met there is the possibility of conducting a radar mapping survey from orbit. 1975 is a favourable year for Venus orbiters since it entails the lowest encounter velocities possible, and thus implies large (and sophisticated) payloads.

Comparison of U.S. and U.S.S.R. Systems

When the 6-metre optical telescope is commissioned in Zelenchukskaya, it is likely to remain unchallenged as the largest ground-based telescope. Larger systems will undoubtedly be constructed in Earth-orbit where minimal gravitational distortion and absence of atmosphere make for the highest possible resolution. Plans have been formulated for 120-in., 240-in. and even 500-in. space mirrors.

The Soviet instrument has a gain of $(236/200)^2$ i.e., 1.4 times that of the Palomar 200 in. reflector. This corresponds to a gain of about 0.5 magnitude. In practice, however, it will be much higher for Zelenchukskaya is in a remote area of the U.S.S.R. where the sky is almost free of artificial light. On the other hand Palomar is now battling against an increasingly bright background sky due to the sodium lights from nearby Los Angeles.

The gain of RATAN over Arecibo is $(576/305)^2$ i.e., 3.5 times. However, this must be modified by the antenna temperature factor of 30/50 and is therefore 2.1 times as sensitive.

Opportunities for CETI

Naturally, there is much interest in the ability of these giant instruments to investigate the nearer star fields for signs of extra-terrestrial intelligence. Although CETI searches have been envisaged by the two astronomical teams, there is an obvious conflict with the demands of conventional programmes of observation.

The Russians have already mentioned the possibility of their two major instruments – the 6-metre reflector and the RATAN-600 – being employed in harness to try and verify the presence of extra-solar planets which have been deduced by orbit perturbations of parent stars. Barnard's Star (which features in the B.I.S. Dædalus Starship Study) is an interesting case in point, since recent work indicates that it may have up to five Jovian type planetary companions [4].

However, whilst this work might help to refine perturbation measurements it would seem doubtful that extra-solar planets of even Jovian dimensions would be resolved in the optical part of the spectrum.

The possibility of using RATAN and Arecibo on very high precision long base line interferometry also must not be overlooked for, with super-accurate radio coordinates, the 6-metre telescope may identify the spectrum and type of the parent star.

The other possibility is that periods of CETI observations could be allocated at some future date to permit searches of the radio spectrum for coherent signals which may bear the imprint of intelligence.

As Professor Carl Sagan has pointed out [5], this might be done both by locking on to individual stars and focussing on nearby galaxies. In the latter case it might be possible to filter out from the "mush" of galactic radio noise of some 2,000 million stars, gas and dust, the "domestic" communications of very advanced extra-terrestrial civilizations.

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CETI SIGNAL TO MESSIER 13

Man's first deliberate attempt to signal to another civilisation in space was made last November when the big dish of the National Astronomy and Ionospheric Center (NAIC) near Arecibo, Puerto Rico, was aimed at the star cluster Messier 13 on the edge of the Milky Way. Sent in binary code at two different frequencies the message, which took three minutes to transmit, will take 24,000 years to reach its destination. It contained a computerised picture of the Solar System, pinpointing the Earth; the outline of a human being; the present population of the Earth, and the fundamental structure of the human DNA molecule in order to show the complexity of life on Earth.

The signal commemorated the re-opening of the newly modified radio telescope. Those principally involved were Dr. Frank Drake, director of the NAIC, and BIS Fellow Carl Sagan, Professor of astronomy at Cornell University.

Messier 13 was selected as the target because the chances of reaching an extra-terrestrial civilisation are so much greater than if signals were aimed at individual stars, or simple binaries. This particular cluster contains some 300,000 stars and the beam width was sufficient to encompass all of them.

The frequencies employed were 1420 MHz and 1610 MHz which correspond to the absorption lines of neutral hydrogen and hydroxyl molecules. The space between these frequencies has often been referred to as the "water hole", it being assumed that any other intelligent life form would use such a system as part of its bio-synthesis.

The experiment has been made possible by the recent modifications to the Arecibo dish (page 53) which have provided improved figuring at these short wavelengths, thus ensuring the narrow beam-width required to enable the output power to reach over this enormous distance. According to Dr. Drake, "If someone in outer space were scanning towards the Earth with radar, he would detect radio emissions 10 million times more intense than that emitted by the Sun."

[Concluded on page 76

After representations to the Australian and British Governments, made some ten years ago by the Australian Academy of Science, and by the Royal Society of London, it was decided in April 1967 to build a large optical telescope, similar in design to the 4 metre telescope of the Kitt Peak National Observatory in the United States. And as a result of discussions held between the two governments and the Australian National University, it was decided that the telescope would be built at the site of the University's own observatory at Siding Spring Mountain (near Coonabarabran, N.S.W.). Under an agreement concluded by the two governments, the costs of the construction, operation and maintenance of the telescope were to be shared equally, whilst the completed instrument would be available equally to astronomers in the U.K. and Australia.

Some two to three years were required for the preparation of detailed design specifications and for the letting of major contracts, which were awarded on an international basis, with important contributions coming from Japan, Switzerland and the United States, as well as from the United Kingdom and Australia. The telescope building and dome were completed by the end of 1972, while the structural components of the telescope itself were assembled during 1973. The present year has been largely devoted to the complex work of adjustment and of the instrumentation of the telescope.

According to the inter-governmental arrangements, mentioned above, ownership of the telescope is vested in the Anglo-Australian Telescope Board. The Board is also charged with the duty of operating and maintaining the telescope. To this end, the Board appointed Professor E. J. Wampler from the Lick Observatory of the University of California as the first Director of the telescope. Professor Wampler took up his appointment on 1 September 1974.

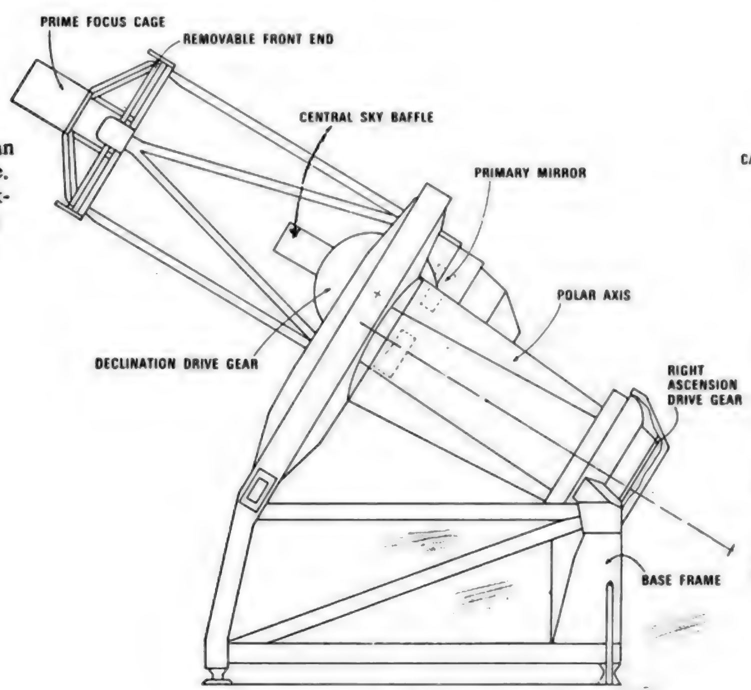
The region of the sky around the southern celestial pole is not observable from the major observatories of the northern hemisphere where all large, powerful telescopes have hitherto been located. This region happens to contain the two galaxies closest to our own, the Magellanic Clouds. It also happens that at the sites of the large telescopes in the northern hemisphere the central regions of our own galaxy appear low in the sky, and can only be studied under poor observing conditions; in the latitude of Siding Spring Mountain however the galactic centre can be observed under good conditions directly overhead. Since it is the centre which exercises a controlling influence over the whole of our Galaxy, astronomers have for long felt that a large telescope in the southern hemisphere would have important advantages over instruments in the north. The strong feeling of the international astronomical community in this respect is now bearing fruit, in the Anglo-Australian Telescope, in the telescope of comparable aperture approaching completion at the Cerro Tololo Inter-American Observatory, Chile, and in the large telescope also in Chile at present under construction for the European Southern Observatory.

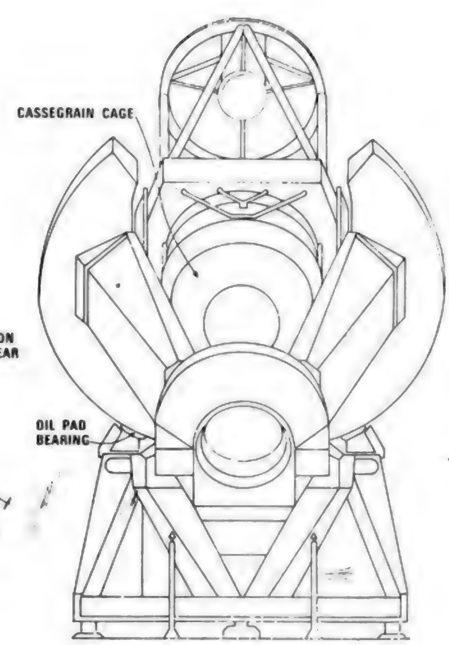
In the case of Australia, there has been a further excellent reason for the construction of a major optical telescope, namely that such an instrument will be an important complement to the Australian commitment to radio astronomy. It has been amply proved in the northern hemisphere that optical and radio astronomy each provides strong support to the other, the solution of some of the most critical problems in astronomy requires observations of both kinds.

The Anglo-Australian 3.9 m Telescope

The heart of the telescope is a circular mirror with a diameter of almost 4 metres. The mirror consists of a block of glass-like material coated at its upper surface by a thin layer of aluminium. The material, called Cervit, has been carefully

The Anglo-Australian 3.9 metre Telescope. Elevations: A. Looking west; B. looking south.





Some facts about The Anglo-Australian 3.9 m Telescope

Altitude of site	1165 m
Latitude	31° 16' 37"
Longitude	149° 3' 58" E
Overall diameter of primary mirror	3.94 m
Working diameter of primary mirror	3.89 m
Diameter of central hole	1.070 m
Thickness of primary mirror at outside edge	0.63 m
Thickness of primary mirror at central hole	0.56 m
Focal length of primary mirror	12.70 m
Mass of primary mirror	16.19 tonnes
Mass of primary mirror plus cell and support systems	43.70 tonnes
Mass of telescope tube assembly	110 tonnes
Mass of polar axis assembly (incl. tube)	258 tonnes
Mass of base frame assembly	68 tonnes
Total mass of telescope	326 tonnes
Diameter of horseshoe	12.19 m
Diameter of dome	36.54 m
Weight of dome (approx.)	560 tonnes
Maximum speed of rotation of dome	72 degrees/min
Maximum height of top of dome above ground level	50.29 m

shaped so that the mirror will bring to a sharp focus the light from any object towards which the telescope is pointed. The mirror departs from an ideal shape by not more than one-ten thousandth part of a millimetre at any part of its surface. This means that if the mirror were to be scaled up to occupy the whole of the 29 km between the Observatory and Coonabarabran its surface would be true to within a centimetre.

To give proper support to a mirror of this high accuracy, the mechanical mounting must also meet very exacting requirements. The axis of the mirror must be pointed correctly to within one-tenth of a second of arc, the angle of the cone subtended by a 1 cm disc at a distance of about 20 km. Since the apparent direction of an astronomical object is constantly changing due to the rotation of the Earth, the mounting must keep the axis of the mirror pointing correctly towards the object under study. This it may need to do for several hours on end. To achieve such a measure of precision, exceedingly accurate bearings and mechanical drive are essential. Such accuracy, usually found only in small high-precision instruments, is here achieved for a telescope with a mass exceeding 300 tonnes.

Adjacent to the telescope are the computers which control its operations. The use of computers greatly simplifies the operation of the telescope itself. To point the instrument toward a specific object, all that need be done is to enter the position of the object on a keyboard. The telescope then swings to the desired position, and continues thereafter to track on the object for as long as required.

A large building surmounted by a rotating dome is needed to house the telescope. The opportunity has been taken in the construction of the building to include space for the ancillary equipment essential to the functioning of the telescope, and for offices and a library. Maintaining the optical and mechanical perfection of the telescope is a difficult task. Because of the high degree of cleanliness required in the dome visitors are not permitted on the main dome floor but are requested to view the telescope from a visitors gallery. This gallery is only open during the day since absolute darkness is required for night-time observations.

In summary the essential optical function of the telescope is performed by about 5 grams of aluminium which coat the surface of a block of accurately-shaped glass weighing some 16 tonnes. This mirror is mounted in a mechanical structure weighing more than 300 tonnes, which in turn is housed in a building and dome weighing some 7000 tonnes. The building is 50 metres in height and 36.5 metres in diameter, dimensions which make the building a prominent landmark in the Coonabarabran area of New South Wales.

LARGE SPACE TELESCOPE

Scheduled for launch by the early 1980's is NASA's Large Space Telescope (LST). This large multi-purpose optical telescope in Earth orbit will enable scientists to probe deep into space – possibly to the limits of the observable Universe, 10 times further than has now been done.

Whereas all Earthbound telescopes have distorted vision because the Earth's atmosphere blurs the view and smears the light, the LST will have peerless visibility.

This large telescope will be launched by the Space Shuttle. It will orbit at an altitude of approximately 330 n. miles (610 km) at an inclination of 28.5° to the equator.

With the LST, astronomers will be able to examine celestial sources such as quasars, galaxies, gaseous nebulae, and Cepheid variable stars which are 100 times fainter than those seen by the most powerful ground-based optical telescopes. Within the Solar System they can monitor atmospheric and surface phenomena of the planets.

The LST is expected to contribute a great deal to the study of little-understood energy processes in celestial bodies, the early stages of star and solar-system formation, the observation of such highly evolved objects as supernova remnants and white dwarf stars, and other studies related to the origin of the Universe.

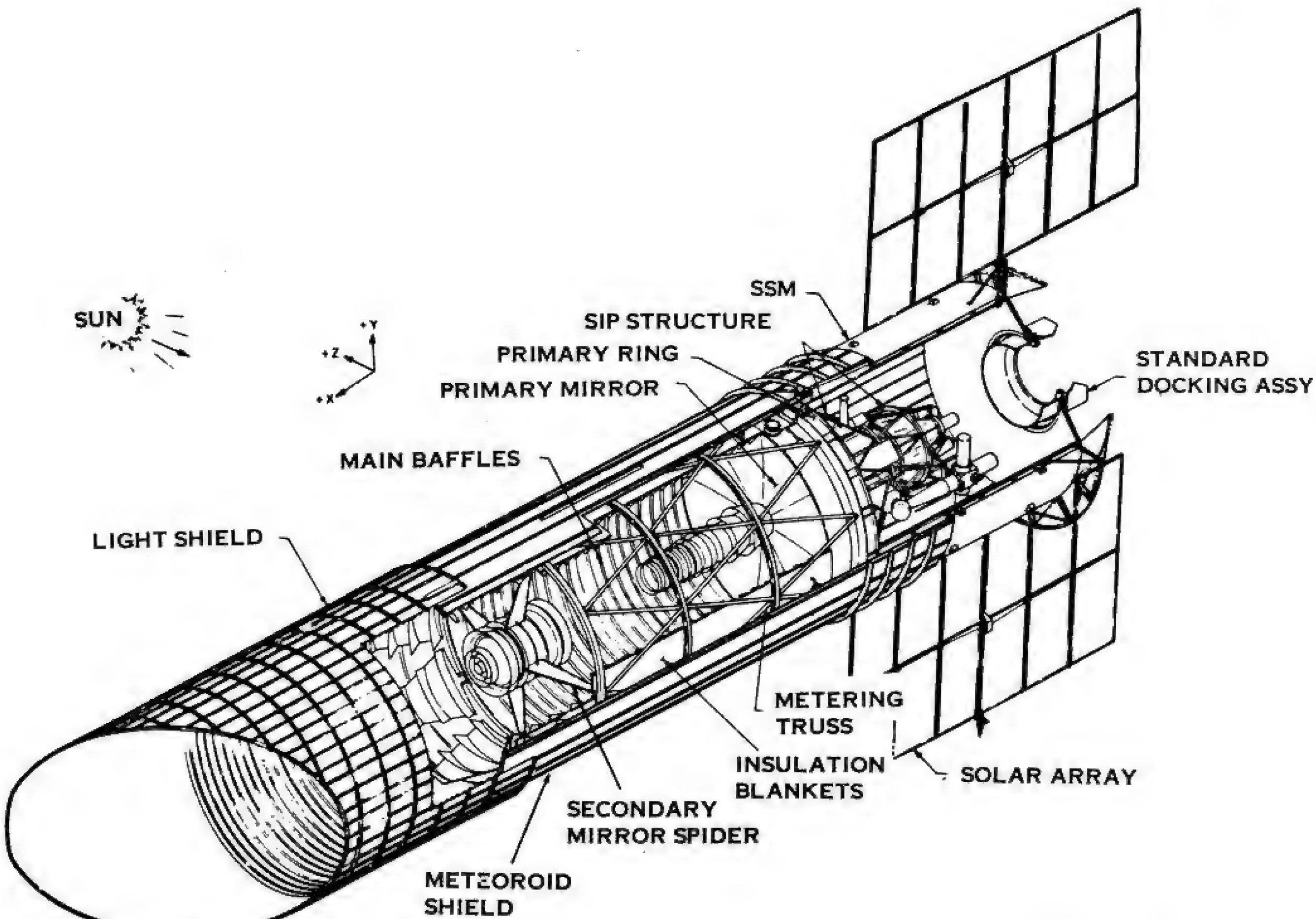
Apart from the many lessons that may be learned about the birth and growth of cosmic structures, the LST will be able to search for planets that many orbit other nearby stars.

The LST will weigh between 20,000 and 25,000 lb. (9000 and 11,000 kg) and will have a length of from 40 to 52 ft. (12 to 16 m) and a diameter of from 12 to 13 ft. (3.6 to 4 m). Its most important optical element will be a primary mirror about 120 in. (3 m) in diameter.

Electrical power to operate the LST will be provided by solar panels on the Sun side of the Earth orbit and by batteries on the dark side of the orbit. Images received by the LST will be transmitted to Earth by television.

The guidance system of the LST will point to an accuracy of 0.2 arc sec and lock onto a target for extended periods within 0.005 sec. of arc. The resolving power of two point images will be about 0.04 arc sec.

The open front end of the LST will be similar to most Earthbound telescopes and will admit light to the 120 in.



The Large Space Telescope (LST) will be approximately 45 ft. (13.7 metres) in length and will weigh approximately 17,640 lb. (8,000 kg). Scientific data from the LST will be telemetered to Earth. Attached to the structure will be the Support Systems Module (SSM) which will provide electrical power, data storage, communications, and automated attitude sensing, pointing and control. The unit also will contain some of the elements needed for orbital servicing and retrieval of the telescope by the Space Shuttle. The LST will be repaired or refurbished periodically and returned to service, thereby providing long-term operational use. In addition to the SSM, the two other principal elements of the LST will be the Optical Telescope Assembly (OTA) and the Scientific Instruments (SI). Preliminary design and programme definition studies for the SSM are being made under NASA parallel contracts by Boeing Aerospace, Lockheed Missiles & Space, and Martin-Marietta. Overall management of the Large Astronomical Telescope is by the Marshall Space Flight Center, Huntsville, Alabama, under the direction of the NASA Office of Space Science, Washington, D.C.

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primary mirror in the rear of the telescope. This mirror will project the image to a smaller mirror in front. The beam of light will then be directed back through the telescope to the output devices in the rear. The clear images provided by the LST will enable scientists to more comprehensively evaluate the mass, size, shape, age, and evolution of the Universe.

The output devices, or sensors, located directly behind the telescope, will communicate images in a variety of ways. Like slices of cake, the modular instrumentation will fit into tubular construction and will contain television cameras, spectrum analysers (to find out about energy levels and material content of objects seen) and light intensity and polarization calibrators. Devices for exact control of temperature, direction, and stability, and the equipment to generate power will be located in similar modular packages.

The Shuttle will not only launch the LST into orbit but will also serve as a base from which astronauts may make repairs and possibly replace instrument packages for new experiments. Each modular package can be replaced in orbit without affecting the overall system. The Shuttle can also bring the LST back to Earth, if necessary, for extensive maintenance or overhaul.

NASA's Office of Space Sciences has assigned the LST project management to the Marshall Space Flight Center, Huntsville, Alabama; the Goddard Space Flight Center, Greenbelt, Maryland, and other NASA centres are also contributing. Scientific guidance for the LST project will be provided by participating astronomers and scientists from universities and observatories.

Although the above article refers to the 3-metre configuration of the Large Space Telescope, smaller optical systems – of 2.4 m and 1.8 m – are being considered to meet possible budgetary constraints.

SPACE SHUTTLE TANKS

Martin Marietta Corporation has been awarded a NASA consolidated facilities contract worth $26,453,600 for preparatory work in connection with the manufacture of external tanks for the reusable space shuttle. Work to be done under the contract at the Michoud Assembly Facility at New Orleans ending 31 August 1978 includes:

(a) Acquisition of plant equipment;
(b) Rehabilitation of existing facilities
(c) Construction of some new facilities and modifications of other existing facilities;
(d) Rearrangements and alterations; and
(e) Maintainance and repair of facilities.

The NASA Marshall Space Flight Center, of which Michoud is a part, is responsible for development of the external tank, solid rocket boosters and space shuttle main engines. The Johnson Space Center has responsibility for the orbiter stage. The external tank will be manufactured at Michoud by Martin Marietta.

SKYLARK OBSERVES THE CRAB

A BAC Skylark research rocket launched from the Spanish National (INTA) Range at El Arenosillo, near Huelva, southern Spain on 7 October successfully observed X-ray emission's from the Crab Nebula at the time of its eclipse by the Moon – an event which occurs only in 11 year cycles. The Crab, a vast cloud of interstellar gas expanding at a rate of 70 million miles a day, is thought to be the remnant of a supernova first recorded by Chinese astronomers some 920 years ago (A.D. 1054).

X-ray emissions have been traced to the Crab Nebula and astronomers have long been interested in more accurately pinpointing their source. Skylark carried complementary experiments from Leicester University, the Max Planck Institute for Extra Terrestrial Research, Garsching and Tübingen University, in Germany. The rocket reached a height of some 119 miles (190 km) and had an experimental observation time of five minutes during which the stabilised payload was pointing at the Crab Nebula.

Skylark was launched from the DFVLR mobile rocket base which is supported by fully transportable launch facilities. It was the fifth Skylark to be launched by DFVLR from the INTA Range and the first from Spain in the British sounding rocket programme funded by the Science Research Council. BAC personnel provided assistance in payload and rocket preparation.

Clear skies and favourable weather conditions throughout the year make the INTA (Instituto Nacional de Tecnica Aerospacial) range and facilities an ideal location from which to launch rocket-borne astronomy and solar experiments.

To date some 330 Skylarks have been launched – with a cumulative reliability of 98% – from Australia, Argentina, Norway, Sardinia, Sweden and Spain.

SERT II RE-STARTS

An electric rocket engine which short circuited on a NASA spacecraft some 4 years ago has been restarted in space, prompting scientists at NASA's Lewis Research Center, Cleveland, to resume the Space Electric Rocket Test (SERT II) mission on a part-time basis. Launched in 1970, the SERT II mission was intended to demonstrate the feasibility of electric propulsion for future space missions such as planetary probes or station-keeping in Earth orbit. The goal was to operate an ion engine for 6 months in space.

The SERT II spacecraft engine thruster 2 shut down after nearly three months of operation, while thruster 1 performed for five months. Scientists suspected each system shorted out when a small chip of metal lodged between two grids at the back of the engine. Apparently the chip eroded from one of the molybdenum grids during thruster operation.

Presumably the sliver of molybdenum which caused the October 1970 short-out of thruster 2 is now gone. William Kerslake, SERT II experiment manager, believes the sliver was jarred loose when the spacecraft was spun-up by its cold gas thruster system to obtain a better Sun angle for the spacecraft's solar arrays. "Spinning the spacecraft created a very small amount of artificial gravity (about 0.0015 of lg) which may have dislodged the chip", Kerslake said. Since then, thruster 2 has been operated successfully a half dozen times for short periods. Up to 60 per cent of its maximum thrust has been obtained.

"A Mercury bombardment ion thruster which can operate after 4½ years in space proves the long term storability of this thruster system design", said Robert C. Finke, Chief of the Electric Propulsion Branch. "The design concepts of the ion thruster, propellent feed system, power processor, and controls can be confidently incorporated into future missions requiring several years of thruster operation".

In 1973, SERT II scientists reactivated the spacecraft for the first time since the test programme was terminated in January 1972. The hollow cathodes in both thrusters were restarted periodically from May to September. The cathode fires electrons into the chamber of the thruster and ionizes the mercury propellent. The ionized mercury is electrically attracted through grids at the back of the thruster to produce thrust. Restarting the cathodes added confidence in ion thrusters for future missions. Such missions would require thrusters to be turned on thousands of times.

To carry out the cathode tests, scientists needed to realign the SERT II solar arrays more directly toward the Sun to convert solar radiation to electric power. Originally the spacecraft travelled in a Sun-synchronous orbit so that the arrays faced the Sun. Gently tugged by Earth's gravity, the spacecraft's orientation gradually shifted from its Sun-synchronous orbit and the solar arrays had inclined more and

more away from the Sun.

A Lewis engineer, Bruce Leroy, suggested a way to give the spacecraft more sunlight. He proposed spinning up SERT II so that its 40 ft. long solar arrays would turn like a windmill in space. It was this manoeuvre that apparently dislodged the sliver of molybdenum.

Resultant rotation of the spacecraft at about 1 rpm exposes more solar array area to the Sun, providing a maximum of about 600 watts of electrical power. Originally, the arrays furnished 1.5 kW.

Late last year, the solar arrays were generating enough power to operate the ion engine for one week every several weeks. During that week, scientists planned to obtain data at least twice a day.

The experiment with SERT II is being conducted by a team at the Lewis Research Center. Data from the spacecraft is relayed from two Space Tracking and Data Network stations to a control room at Lewis.

PRODUCTS FROM BASALT

A report from the Soviet Union that building materials and insulation fibres have been made from basalt* has opened up the possibility of extending such manufacturing processes to the Moon. The original announcement, reported by the Novosti press agency, says a fibre made from basalt has been produced experimentally by a research team in Kiev. The material can be used like cotton wool, in sheets or in fibre board. It comes in grades of microfine (about half a micron thick) or superfine (one and a half microns thick). It can be used over a range of temperatures from 260°C to 700-900°C. A cubic metre of the superfine fibre weighs no more than 33-37 lb. (15-17 kg).

Basalt fibre cardboard tested at the Azovstahl open-hearth plant in the Ukraine was found to be superior to asbestos slabs. A 2.75 in. (7 cm) layer is sufficient to replace a 3.3 ft. (1 metre) brick wall. The soft basalt fibre will find application in the refrigerator industry, replacing glass fibre cotton. The use of fibre at the Kuznitsa works in Kiev for boiler insulation in ships, the report states, has brought about a marked reduction in the weight of boilers.

Basalt-made fibre is sound absorbent. Superthin grades have been used for floor mats overlaid with glass fibre. They are fireproof.

Even more exciting opportunities may be opened up in zero-g manufacturing processes which may be carried out in space stations, perhaps deriving basalt from the Moon (see "Take-off Point for a Lunar Colony", *Spaceflight* September 1974, pp. 322-326). The first specimens of basalt plastics produced by the Soviet research team were hinges which look like plastic but are one and a half times as light as aluminium ones. In strength they are comparable to steel. Basalt plastics, say the Russians, can be used in building radio-transparent structures when metal would create interference. The research team is now studying the possibility of welding such structures.

They have already found that a basalt thread as lustrous as silk can be knitted. The colour is dark brown. Such fabric could be used for heat-resistant clothes, or for welders' overalls. The superfine material could be used as a filtering material in the medical and chemical fields.

* *Basalt: A fine-grained, igneous work of high density and dark colour, composed mainly of plagioclase and pyroxene.*

ZERO-G DROP TESTING

A large capsule dropped along guide rails inside the structure of a Saturn V test stand and boosted to a speed in excess of free fall is saving money and time by providing brief weightless periods for materials processing and other experiments at Marshall Space Flight Center.

From April 1970, to the end of May 1974, 30 drops were performed, ranging from material processing experiments to cloud physics investigations. The 430 ft.-tall building was originally constructed as a Saturn V Dynamic Test Stand. The total drop facility height inside the building is 334 ft., with a free fall height of 294 ft.

Vaughn H. Yost, Technical Manager for Material Processing Drop Testing at MSFC, says studies have shown that the facility provides many advantages over other methods of zero-g testing, one of which is the lowest cost.

The capsule is 24 ft. long and seven ft. in diameter. With the 450 lb. experiment test package on its floor, the capsule weighs nearly 4,000 lb. Air thrusters are turned on when the capsule is released, speeding it toward the ground faster than free fall. As a result, the experiment package loses contact with the floor of the capsule for up to 4.2 sec.

SOLAR RECORDER

A recorder to evaluate solar energy available in any area of the world where ambient temperatures are between −40 and −125 deg. Fahrenheit has been designed by the IBM Federal Systems Division at Huntsville, Alabama, under contract to the Marshall Space Flight Center.

The recorder will give engineers enough data to plan and build equipment to convert solar energy into power. The fully automatic device, used in a specific area or distributed throughout the country to record "sunfall" measurements, will store the readings in a centralised location and will record the data in a computer format. It will measure the direct solar radiation, the total (direct plus diffuse) solar radiation, and the solar collector's efficiency.

The recorder also will provide the necessary solar radiation measurements vital to the efficient design and development of converters prior to any large-scale construction.

NEW CETI COMMITTEE

Since 1965 the International Academy of Astronautics (IAA) has been concerned with the subject of CETI (Communication with Extra-Terrestrial Intelligence) and has already organised three International Review meetings, the latest one being held on 4 October at the IAF 1974 Congress in Amsterdam.

In view of the growing interest in CETI and the theoretical and practical experimental studies which are now being pursued (especially in the USA and USSR), the IAA has now decided to form a new permanent Standing Committee with the brief to discuss, handle, and deal with all aspects of CETI and related subject matters.

The new Committee held its first meeting in Amsterdam on 5 October under the Chairmanship of Professor R. Pesek. The following resolutions were agreed:

(a) That the IAF should hold a further International

Review Meeting at the proposed 1975 Congress.

(b) That a minimum of 5 suitable papers from the UK, USA and USSR should be presented at this meeting.

The initial Committee Membership was as follows:

Messrs. Pesek (Czechoslovakia), Sukhotkin (USSR), Subotomize (Poland), Rogosov (Sweden) and Lawton (UK).

Other suitable candidates were to be approached by existing Committee Members.

This new Committee is a firm step forward in the formal recognition of CETI as a subject now capable of being analysed, discussed and evaluated in precise scientific terms. As such, it has made history; it is the first International Committee to be formed and formally charged with the task of dealing with matters specifically related to CETI.

It is almost certainly going to be one of the leading bodies dealing with this subject, and it is a tribute to the major contributions made by the BIS that one of its members has been specifically nominated to act as the UK representative.

The inauguration of the new Committee and a summary of its initial recommendations was formally presented to the 1974 IAF Congress by the IAA President (Dr. C. Stark Draper) at the closing ceremony on Saturday 5 October 1974. We wish the new Committee "Bon Voyage".

CANADIAN CETI PROBE

Canadian astronomers have begun a search for extra-terrestrial radio signals of intelligent origin using the 150 ft. diameter radio-telescope at Algonquin, Ontario. Researchers R. Feldman of York University and A. Bridle of Queen's University say they will concentrate on six stars intensively and 300 to 500 others more briefly.

The search will continue for at least a year. All the stars have been chosen because they are non-variable, to give time for intelligent life to evolve. They are also slowly rotating stars which, according to one theory, suggests the presence of planetary companions.

IRAN TO BUILD ERTS STATION

More of the developing countries are now following India's example in putting space technology to practical advantage. Iran is to build a ground station to receive data directly from NASA's experimental Earth resources satellites. Brazil had previously agreed to do so.

The new station, to be built in the Tehran area, will complement existing U.S. ground stations at Fairbanks, Alaska; Goldstone, California; and at the Goddard Space Flight Center in Greenbelt, Maryland. Foreign stations are already in operation at Prince Albert, Canada and Cuiaba, Brazil. A third foreign station is now under construction at Fucino, Italy, with full operation expected in mid-1975.

In exchange for rapid access to satellite-gathered information about conditions on the Earth's surface, Iran will make copies of the imagery and computer-compatible tapes they produce available to NASA.

Iran will bear the full cost of constructing and operating the new facility, will relieve NASA of the responsibility for providing satellite data to selected scientific investigators in the region and will also supply data to the general public in the area surrounding the new station.

Under the agreement signed in Tehran on 29 October 1974, NASA guarantees free access to the first experimental Earth Resources Technology Satellite, ERTS-1, for as long as it continues to operate, and to the second ERTS satellite, ERTS-B, at least during its design life of one year. Following that period, NASA has the option to establish some cost-sharing arrangement for participating ground stations.

The Iranian station will be available to offer emergency support in the event of a satellite malfunction. If, for example, tape recorders aboard an Earth resources satellite should fail, all the co-operating Earth resources ground stations – including the new facility at Tehran – might be asked to grant special assistance and to provide additional copies of transmitted data.

Data relayed from ERTS-1 has already been distributed to some 300 investigators in the United States and 37 foreign countries. Their investigations include such diverse areas as agriculture, forestry, urban and regional development, pollution monitoring, oceanography and geology.

ARTIFICIAL AURORA

A Soviet accelerator of electrons is to be launched into space during the winter by a French rocket from Kerguelen Island in the southern part of the Indian Ocean. Announcing this, Academician Boris Petrov, who is chairman of the Intercosmos Council, said that the experiment was intended to study the nature of the polar lights.

The Ukrainian electron accelerator – part of the Franco-Soviet Arax experiment – makes it possible to produce an aurora by artificial means, so that the nature of polar lights can be studied more thoroughly than hitherto.

The electrons thrown out by the accelerator will intrude into the ionosphere above the north of the U.S.S.R.

ASTP "SOLAR ECLIPSE" EXPERIMENT

An artificial solar eclipse that they alone can see will be produced by the American and Russian crews on their joint space mission in July 1975. Astronauts and cosmonauts will work together during the 10-day joint Apollo Soyuz Test Project.

They will be producing the artificial eclipse, to be seen from the Russian Soyuz spacecraft, in order to see and photograph the solar corona – the atmosphere of the Sun.

This atmosphere is much fainter than the surface of the Sun. To prevent light from the surface coming through, the Apollo spacecraft will be used an an occulting device, producing the artificial eclipse.

The experiment will allow space photography to be performed of the extended solar corona as well as the spacecraft-associated environment around the Apollo vehicle which could develop from outgassing of sealed compartments, degassing and sublimation of outer structural materials of the

spacecraft or firings of the attitude control thrusters.

In the experiment, the Apollo will first align the Soyuz toward the Sun. Then, shortly after spacecraft sunrise, the Apollo will undock from the Soyuz and back away toward the Sun. As the distance between the two spacecraft increases, more of the solar corona will be exposed to the field of view of the motion picture camera mounted on the Soyuz. During separation, this camera will automatically take sequences of photographs with varying exposures.

An attempt will be made to correlate the observed coronal structure with surface activity on the Sun, which is to be observed simultaneously with ground-based instruments.

Principal investigator for the experiment is Dr. G. M. Nikolsky of the USSR. American co-investigator is Dr. R. T. Giuli of NASA's Johnson Space Center, Houston, Texas, Dr. Giuli is also the programme scientist for the other experiments to be performed jointly with the USSR or unilaterally by the United States.

COUSTEAU WORKS WITH SATELLITE

Capt. Jacques Yves Cousteau's famed research vessel *Calypso* will undertake a variety of oceanographic and weather experiments for NASA in cooperation with the Texas A & M University as part of Captain Cousteau's latest study of the ecology of the oceans. As part of a broad exploration of the marine environment, the *Calypso* researchers are measuring the chemical content of seawater, temperature, depth factors, water colours and kinds and quantities of pollutants present in various regions.

The *Calypso* left Galveston, Texas on 15 October to begin a nine-month voyage through the Gulf of Mexico, the Caribbean Sea and the eastern Pacific Ocean off Mexico and South America. Weather and oceanography experiments sponsored by NASA and Texas A & M are being carried out with the aid of satellites and high-altitude aircraft such as the U-2, in flights over the *Calypso*.

Companion equipment, designed to translate space-collected data quickly and efficiently into usable forms, is carried aboard the floating laboratory, including satellite communications equipment and an Applications Technology Satellite-3 (ATS-3) surface terminal which permits daily contact with NASA's Goddard Space Flight Center in Greenbelt, Maryland, and Texas A & M in Houston. Four graduate students from the university will travel aboard the *Calypso* to assist with the NASA onboard experiments, under the supervision of their professors.

The vessel also carries an Automatic Picture Transmission (APT) system, an array of instruments that receives visual and infrared pictures from satellites continually, during the day and at night. The APT photographs aid in the scheduling of U-2 flights; the infrared capability of the system is used to measure ocean and weather conditions.

Calypso technicians are making use of a NASA-developed device called a "Scatter Meter", which samples seawater continuously as it flows through a special cell. A laser beam scans the cell and measures various angles of reflectance to detect organic and inorganic matter and contaminants.

The U-2 carries a Coastal Zone Colour Sensor which is being developed for later flight on the Nimbus-G satellite scheduled for launch by NASA in 1978. The sensor is capable of measuring such factors as pollution, turbidity, chlorophyll content, salinity and water temperature by correlating the subtle shades of colour to actual conditions measured from the ship.

Another sensor, carried on the polar orbiting Nimbus-5 and Nimbus-F (to be launched this year), measures water content in clouds, rain rate and liquid droplet size. Called an Electronic Scanning Microwave Radiometer, its readings will be measured against those taken under its track by the *Calypso*.

The sophisticated equipment used in the *Calypso* studies and the synchronized approach – in which appraisals of weather and water conditions collected by satellites and high-flying U-2s can be measured against similar data collected by traditional means at the sea surface – is seen by scientists as an important evolutionary step toward fast and accurate assessments of significant aspects of ocean ecology. For instance, the important ocean phenomenon called upwelling, in which nutrients are churned up to the surface by underwater currents, may be detectable by space photography. Upwelling often signifies the presence of plentiful quantities of fish, inasmuch as the feature acts as a trigger to increase the concentration of nutrients such as plankton, the sustenance of many small ocean creatures.

The concentrations of small feeding fish at upwelling sites often attract larger ocean predators in commercial quantities. If a surface vessel such as the *Calypso* is able to verify the fishing circumstances as favourable, commercial fishing fleets could be quickly summoned to productive fishing grounds.

This approach was tested recently in a series of experiments completed through the cooperative efforts of NASA and the National Oceanic and Atmospheric Administration. Stocks of menhaden (a fish caught in enormous quantities and used for industrial purposes) were studied in the waters of Mississippi Sound, using remote air-and-satellite-borne sensors.

Locations of large schools of the fish were eventually correlated with readings of salinity, colour, and transparency of ocean waters collected from space. Commercial fishing boats and surface research vessels corroborated the findings and fishery scientists agreed that data obtained by space vehicles could be of inestimable value to commercial fishing fleets.

Monitoring of the cruise pattern of the *Calypso* by NASA satellites has been done on past expeditions and the research ship also has carried space agency equipment designed to assess weather and oceanographic conditions in various parts of the world's oceans. During the last *Calypso* expedition, a hazardous voyage that ended in 1973, Captain Cousteau called the satellite assistance the *Calypso* received "the most valuable tool we had to plan our trip".

OAST APPOINTMENT

Dr. Alan M. Lovelace, formerly Acting Deputy Assistant Secretary of the U.S. Air Force for Research and Development, has been appointed Associate Administrator for NASA's Office of Aeronautics and Space Technology (OAST). One of six major Headquarters offices which direct NASA's research and development programmes, OAST has the responsibility for providing the technology to meet the nation's future requirements in aeronautics and space exploration.

ARMAGH ASTRONOMY CENTRE

By Terence Murtagh*

Since it opened in 1968 the Armagh Planetarium has been a resounding success not only as a tourist attraction but perhaps more importantly as a centre for educational astronomy. With its 40 ft. projection dome, "Go to "MARS" projector and comfortable aircraft seats for 150, this is the largest educational planetarium in the British Isles, with some 95 per cent of lecturing time devoted to school parties.

Teachers wishing to bring groups of children are encouraged to attend with single classes only, thus enabling proper attention to be given by the lecturer to students' questions and discussion. All age groups and intelligence levels of children can be coped with during the live planetarium displays and teachers have a wide choice of lectures ranging from "Legends of the Stars" for the five to six-year olds to the more detailed lectures for 'A'-level students, Open University students, teachers, etc.

In recent years I have had requests for lectures for deaf and dumb children, those with mental handicaps and children from training schools. Naturally, most of these require special lecturing techniques, particularly the deaf children who of course could not hear the lecture. In that case slides were projected onto the star sphere with the appropriate commentary whilst written notes were used during a number of breaks when the main lights were turned up. In addition, an interpreter was used so as to enable the children to communicate with, and question, the lecturer.

However, even with all its equipment, the Planetarium lacked a number of important features, e.g. although the foyer could accommodate 150 or so, there was no room for exhibits, and films could not be shown.(The curved surface of the dome causing too much distortion, besides the fact that half of the audience were looking in the wrong direction). Notes cannot be taken in the Star Theatre which, although ideally equipped to show the night sky, does not lend itself very readily to conventional classroom experiments and work.

So in September 1971 I began work on an extension to the planetarium, to be called the Hall of Astronomy – the original idea having been thought of many years before by the founder of the planetarium, Dr. Eric Lindsay, the late Director of Armagh Observatory.

The first task to be accomplished was that of raising the money, at that time an estimated £40,000. Having had discussion with representatives of the two local authorities at that time(Armagh County and Urban District Councils) and the Ministry of Commerce, I learned that a suitable scheme could be financed; I therefore set off on a three week study tour of U.S. planetaria, concentrating on those with strong educational links. During my visit I obtained sufficient information to enable me to return home and begin to draw up the plans for a suitable building to be costed and designed.

By the end of 1972 plans were well advanced although the cost had now risen to some £63,000 – small compared to the final costing of £100,000! July 1973 saw the work begin and by September 1974 the Hall of Astronomy was complete and ready for action. For £100,000 we had a large exhibition hall, classroom, colour television studio, library, store, small exhibit area and new offices.

In the course of 1974 part three of the project was begun when the site for the first public observatory in Ireland was prepared and finance provided by the Northern Ireland Department of Commerce for the provision of a five-metre observatory, to be sited on a raised concrete platform at the rear of the existing planetarium Hall of Astronomy site.

It is planned to house in the dome a 16in. F/20 Dall-Kirkham reflector on a cross-axis mounting. A Pacific Photometric Instruments 2401 photometer has been purchased for use with this instrument and will be available for use by individual amateur astronomers or school groups. For solar work a 75 mm refractor has been fitted with ultra narrow band filter (0.5-0.6 Angstrom passband) operating at the hydrogen-alpha wavelength of 6562.8 Angstroms. By means of closed-circuit TV telescopic views of the Sun, Moon, and planets can be relayed to exhibits in the Hall of Astronomy or recorded on video tape.

In the exhibition hall there is a static exhibition on the exploration of the universe by modern astronomical methods, providing such essential and detailed information which it is not possible to give in the course of a planetarium display. Pupils can also take notes and take time to study diagrams and photographs which relate to their lectures and school work.

In addition to the static displays there are four experimental bays in which actual equipment can be used by the visitor to demonstrate in actuality some of the concepts or observational techniques just described in the ordinary exhibits.

In Bay One for example, light is analysed and by the use of direct-vision spectroscopes it is possible to prove the existence of certain elements in the Sun and other stars. Also in this bay is an electronic version of the Hertzsprung-Russell diagram, as an introduction to stellar evolution.

Bay Two deals with the measurement of distance in the Universe and the important role played by the Cepheid Variables. To illustrate the fact that the sky is really three dimensional, and not two as it appears, there is a 3-D model of the constellation Orion on a rotating base, thus allowing the viewers to grasp the depth of the sky, the illusion of the constellations and the truth of not believing all one sees.

Radio astronomy is covered in Bay Three which is a large control console controlling a steerable solar radiometer situated on the front lawn and a static receiver for meteor detection. Both receivers are attached to pen recorders and the movement of the solar radiometer can be observed on a small television screen receiving pictures from a camera mounted in part of the building from which the 20 ft. dish aerial is observed.

In Bay Four we deal with the motions of the Earth in space and by the use of a number of electric orreries it is possible to observe the relative motions of the planets in relation to distance from the Sun, study the changing aspects of the Earth as it moves around the Sun, yet keeping the axis constant, and see the Earth's revolution.

Beyond the exhibition hall is the classroom with its own exhibit cases containing part of the historic collection of Georgian telescopes owned by Armagh Observatory, plus many items on loan from the Science Museum, London. The classroom, which seats 50, is complete with all necessary accessories including an overhead projector and weather satellite picture-receiving station.

On the first floor above the classroom is an exhibition room of similar size. The front "wall" of this room is made of three screens which are used for back-projection providing a constantly changing view of man's conquest of the heavens. These screens however are not permanent and can be removed and replaced by balustrades, thus allowing this room to be

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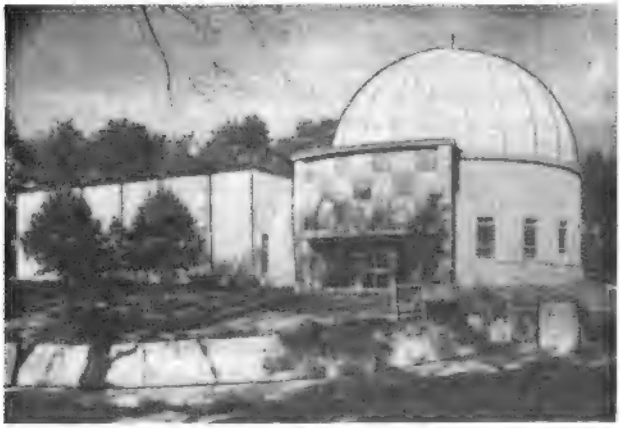
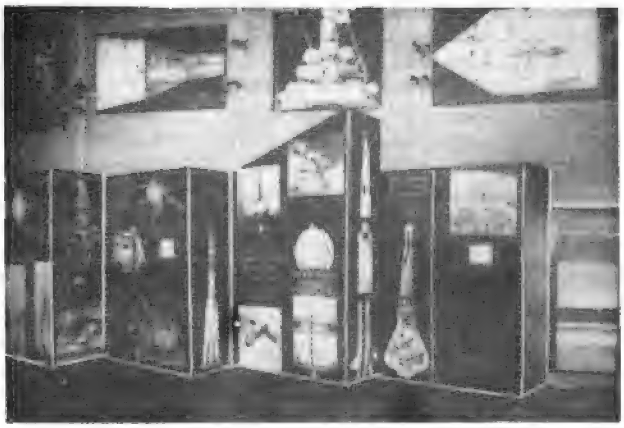
* *Director, Armagh Planetarium*

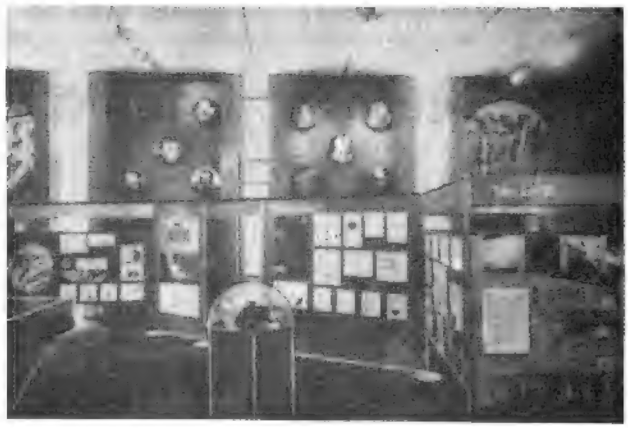


Exterior view of Planetarium and Hall of Astronomy with solar radiometer in foreground.

Looking down main exhibit area to classrooms. The three large screens are removable to form a balcony on 1st floor display area.



'History of Space' exhibit showing video monitors.



Looking across to experimental bays nos. 1-4.

Ground floor classroom area with experimental bay 4 and one of the historical exhibits in background.

The fine collection of Georgian instruments, many of which were the personal property of King George III.

used as an exhibit room and balcony from which the complete floor of the exhibit hall can be viewed.

Next door is the video studio, equipped with three black and white and one colour camera together with appropriate lighting and control facilities. Programmes can be recorded off/air (from the usual channels) film transferred to tape or programmes made up in the studio. The studio is equipped with two half-inch reel-to-reel colour video recorders made by Shibaden – one of which has the facility of electronic edit. From the studio programmes may be relayed to colour monitors in other parts of the building or to the reception desk where there is a control panel for programme distribution either from the studio or the cassette, and cartridge video recorders stationed there. The video tape library is in the process of being built up but it is still possible to request showings of films and programmes for schools or individuals. The static exhibits in the exhibition hall have reference to programmes and films which contain more information relating to that particular subject. Such requests can be viewed in the comfort of the classroom on a 26 in. colour monitor.

Beyond the video studio is the conventional library which will be made available to individual or groups requiring reference, or in some cases loan facilities.

All the facilities now available at Armagh have been offered to amateur astronomers in Ireland at no cost to them. Such facilities include use of the planetarium, observatory telescope, library and video equipment.

Apart from the offices and stores this completes our tour of the newly named Lindsay hall, for although he lived to see this, in many ways, "impossible dream" come true, Dr. Lindsay died on 27 July 1974.

Early 1975 should see the final phase of the project complete with the opening of the public observatory. Armagh will then have an educational astronomy complex which will far surpass anything currently available not only to schools in the U.K. but also in the whole of Western Europe.

The possibilities of such a complex are inspiring, particularly as our aim is not to turn out masses of professional astronomers, but to simply turn more eyes towards the sky, so that armed with the knowledge of modern astronomy people can grow aware of the drama of the Universe, follow the plot of Creation, learn the story of Nature itself and participate in it all through the "cosmic connection" that only astronomy can give.

JET PROPULSION LABORATORY

By Mike Howard

Introduction

On 31 October 1936 a group of students of the Guggenheim Aeronautical Laboratory, California Institute of Technology (GALCIT), fired an experimental liquid rocket engine in the Arroyo Seco riverbed at Pasadena. From that firing stemmed the GALCIT Rocket Research Project in 1937 under the leadership of Dr. Theodore von Kármán which soon attracted government sponsorship and led to the establishment of the Jet Propulsion Laboratory (JPL) on 1 November 1944.

JPL's History

Situated in the shadow of the San Gabriel mountain range, JPL soon became involved in guidance and electronics for missiles. During the years 1945-47 JPL developed the WAC Corporal surface-to-surface missile utilizing the proving grounds at White Sands, New Mexico. Commencing in May 1948 a series of Bumper WAC vehicles was launched as part of the U.S. Army Ordnance/Caltech ORDCIT Project begun in January 1944 to develop long-range guided missiles. The Bumper WAC comprised a WAC upper stage mounted on a V-2 rocket and it was one of these vehicles, Bumper WAC No. 7, that on 24 July 1950 became the first missile to be launched from Cape Canaveral. Guided missiles specifically developed by the ORDCIT project were the LOKI anti-aircraft weapon and the Sergeant surface-to-surface missile.

Under the sponsorship of the U.S. Army, JPL produced the spacecraft and upper propulsion stages of the first U.S. satellite, Explorer 1, which after its launch on 1 January 1958 detected the Earth's radiation belts. On 1 October 1958 the National Aeronautics and Space Administration was formally established and two months later took the Jet Propulsion Laboratory under its wing.

JPL Today

Today the Jet Propulsion Laboratory is staffed by some 4000 scientific, engineering, and administrative personnel and performs three main functions: Exploration of the Solar System utilizing unmanned spacecraft; operation of the world-wide Deep Space Network which is responsible for tracking and communications during deep space missions; and basic research and advanced development in a broad spectrum of scientific and engineering disciplines.

In addition to the main complex at Pasadena, JPL maintains a number of off-laboratory facilities including an astronomical observatory at Table Mountain, California; a rocket test station adjacent to Edwards Air Force Base, California; a launch operations site at Cape Canaveral, Florida; and stations of the Deep Space Network in Spain, South Africa, Australia, and at Goldstone, California.

To fulfil its responsibility for the transfer of space technology to the civil sector JPL has established the Civil Systems Program Office. This office coordinates efforts in the application of space technology to important national problems including urban studies, medical engineering, and public safety support.

An important part of the Jet Propulsion Lab's complex is the Space Flight Operations Facility (SFOF) which is to unmanned spacecraft the equivalent of the Johnson Spacecraft Center's Mission Control Center to manned craft. First used in July 1964 during the Ranger 7 lunar mission the SFOF has provided multiple-mission control for a number of

NASA/JPL projects including Mariner, Surveyor, Pioneer, and Lunar Orbiter. Most recently the SFOF has been involved with the Pioneer 10, Pioneer 11, and Mariner 10 missions which continue to occupy its attention at the present time.

Spacecraft

The Jet Propulsion Laboratory has, of course, been deeply involved in many spacecraft families. Ranger was developed by JPL to establish whether there were large enough flat areas on the lunar surface for a manned landing. Ranger 1 was launched on 23 August 1961 to test in Earth orbit spacecraft performance for future lunar photographic and science missions. Rangers 3-5 were designed to obtain television pictures of the Moon and attempt to land a seismometer package on the surface. Each one failed although in two instances there was trouble with the launch vehicle.

As a result, the last four Rangers were simplified so that the main task was to obtain close-up TV pictures from six cameras before they plummeted to destruction on the lunar surface. The first Ranger of the four again experienced a failure and things began to look bleak for the lunar landing programme since the mapping of the Moon's surface was an essential prerequisite. However, on 31 July 1964, after almost 3 years of frustration, Ranger 7 returned 4316 high-resolution pictures of the lunar surface showing objects only 1.5 ft. across before impacting in the Sea of Clouds.

The problems and disappointments of Ranger now seemed to fade away as the final two spacecraft of the series, Rangers 8 and 9, returned 7137 and 5814 pictures respectively to bring the project to a successful conclusion.

The Rangers showed that the surface was clear enough to attempt a manned landing. However, it was still not known whether it would take the weight of a landing craft; the task of finding out fell to small robot spacecraft of the Surveyor series. Surveyor was a series of 7 lunar probes designed to soft-land and return pictures and data from the lunar surface. Each craft was fitted with a single television camera and a rotating mirror. By photographing the mirror image this one camera could transmit a view looking in any direction. Also on the Surveyor was a surface sampler scoop and various instruments operated by spacecraft controllers nearly a quarter of a million miles away in the Jet Propulsion Laboratory. These robot vehicles allowed the first rudimentary analyses to be made by U.S. scientists of the lunar surface. Of the 7 Surveyors, 5 successfully soft-landed on the Moon to return a combined total of almost 90,000 photos.

The triumphant lunar landings of the Apollo programme which followed stand as a record to the pioneer work of Ranger and Surveyor spacecraft and a third series called Lunar Orbiter which was managed by NASA's Langley Research Center.

Over the past 12 years there is one family of spacecraft that has visited 4 separate planets and by the early part of the next decade is scheduled to probe at least 2 more. On 14 December 1962 Mariner 2 became the first successful interplanetary spacecraft when it passed 21,685 miles from Venus and reported back that the Venerian surface temperature was in the region of 800°F. Five years later Mariner 5 passed within 2500 miles of the planet to further probe its cloud blanket.

More recently Mariner 10 returned TV pictures of Venus as it used the planet's gravitational pull to swing itself in towards Mercury becoming the first spacecraft to use this principle and the first craft to visit the Sun's innermost planet.

The major Mariner effort has centred on Mars. During the Mariner 4 fly-by of the Red planet on 14 July 1965 the spacecraft returned 22 TV pictures covering some one per cent of the planet's surface. Mariners 6 and 7 which flew by Mars in 1969 improved on this by returning some 200 pictures of Mars though it was not until 1971, when Mariner 9 became the first man-made object to orbit another planet, that the mapping of Mars began in earnest. For almost a year Mariner 9 photographed the Martian landscape as it circled the planet twice each day successfully charting the entire surface.

Future Projects

Future missions for which JPL has some responsibility include Project Viking and the Mariner Jupiter/Saturn mission.

During 1976 two Project Viking spacecraft each consisting of a lander and an orbiter module are scheduled to reach Mars. While the lander, under the management of the Langley Research Center, probes the Martian surface, the orbiter, directed by JPL, will observe the planet from above.

The following year, 1977, two 1,500 lb. Mariner class spacecraft will be launched towards Jupiter to continue the work of Pioneers 10 and 11. Jovian encounter is due in 1979 at which point the spacecraft will use the gravity assist technique, tested and proven by Mariner 10, to fly on to an encounter with Saturn in 1981. The mission is designed to encompass scientific exploration of interplanetary space, Jupiter and Saturn, and selected satellites of the two planets.

Deep Space Network

The Deep Space Network (DSN) was designed, developed and continues to be managed by the Jet Propulsion Laboratory for NASA. This network is used to track lunar, planetary, and deep space probes through its world-wide network of Deep Space Stations. Six stations with 26 metre antennae have recently been supplemented by three new 64 metre stations. These stations provide command, tracking, and telemetry coverage of spacecraft and are linked to JPL through NASA's communications network, NASCOM.

Epilogue

Ever since its inception the staff of the Jet Propulsion Laboratory have pioneered advancements in space research and they show no sign of taking a back seat just yet. In the January-February 1973 issue of JPL's in-house journal *Lab/ Oratory* appeared a quotation by Foss which seems to symbolise the Jet Propulsion Laboratory and its siting most aptly: "Bring me men to match my mountains, bring me men to match my plains, men with empires in their purpose; and new eras in their brains".

Acknowledgement

The author wishes to thank the staff of the Jet Propulsion Laboratory's Public Affairs Office for their assistance in the preparation of this article.

Further articles in this series will deal with the Goddard Space Flight Center at Greenbelt, Maryland; Wallops Flight Station in Virginia, and Ames Research Center near Mountain View, California.

T 26

PRIME POWER FOR THE SHUTTLE

By Robert Edgar

Introduction

"This is one of the truly advanced components making up the Shuttle system". So spoke Robert F. Thompson, NASA Shuttle Programme Manager, before the U.S. government subcommittee responsible for Manned Spaceflight on 27 February 1974. He was describing the Space Shuttle Main Engine (SSME), whose core recently underwent the first "hot" firing of a test series which should lead to a firing of a complete engine prototype this year. "Its performance will be well above that for any of today's engines", Thompson continued. "To design a vehicle which could combine the activities of a launch rocket, an orbiting spacecraft and a high-performance aircraft demanded a very efficient main power plant".

The test series began in October of 1973 when SSME's ignition subassembly was successfully operated in simulated flight conditions. The milestone test, the "hot" firing, was performed on the central propellent heaters, the 'preburner assembly', (ringed in Fig. 1) which will be described later. Ignited by a spark plug, the assembly was fired for 3.5 sec. on 14 April. These burners, only 188 mm (7.5 in.) in diameter, have to cope with a very considerable volume of propellents. They ingest 3,400 gallons of hydrogen and 140 gallons of oxygen per minute.

These and other similar activities are taking place at the Santa Susana Test Facility which is operated by Rockwell International, the prime contractor, on behalf of NASA. The facility, constructed as part of the S-II (Saturn V second stage) development programme, is located in a rough, boulder-strewn depression in the Santa Susana Mountains outside Los Angeles, overlooking the San Fernando Valley, and includes two test stands which once accepted the S-II.

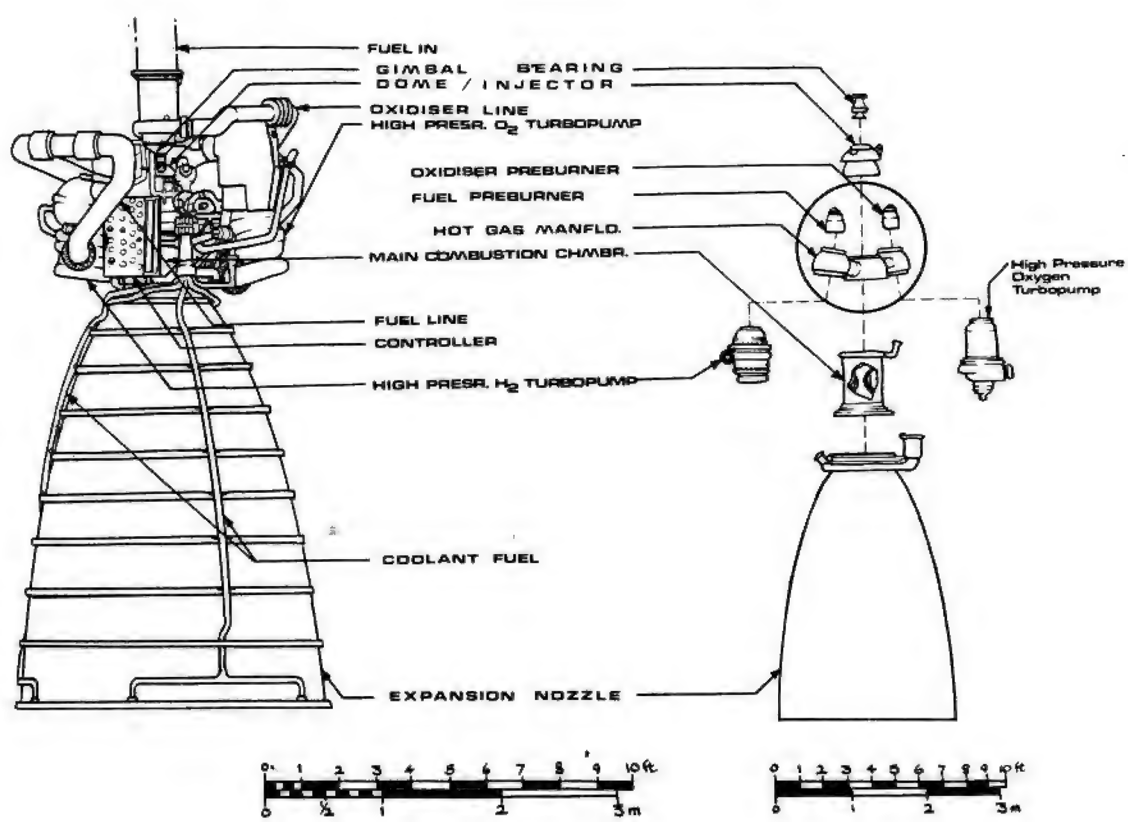
When the design and performance checking of each element is complete, a prototype of the engine will be put on trial at Santa Susana and also at the Mississipi Test Facility of NASA, which was also built as part of the S-II project.

Contract and Development

The engine is being designed and built under a contract which will probably extend over 8 years, awarded to the Rocketdyne division of the Rockwell International Corporation, Canoga Park, California. Feasibility studies – conducted by each company competing for a NASA contract – were initiated by Rocketdyne in April 1969; and the contract go-ahead (worth $465,000,000 to the winner) was received in April 1972.

The SSME programme itself began with Phase "A", the development stage, which is scheduled to end in March 1976 with the Critical Design Review (CDR). The second part of the programme, Phase "B", includes integration of the engine into a Shuttle Orbiter vehicle and the first flights – horizontal, vertical and finally orbital. So far, only a definition study for Phase B has been made, but it seems very likely that Rocketdyne will finish what they started.

Following CDR, two major milestones in Phase B must be passed before SSME's development is complete. A Preliminary Flight Certificate (PFC) must be obtained; this involves delivered flight engines passing a "life test" of 2.5 hours cumulative operation, including 35 starts, to prove that they are safe, reliable and capable of performing the mission. This compares with the engine's life of 100 starts and 7.5 hours cumulative operation without overhaul. Next, the First



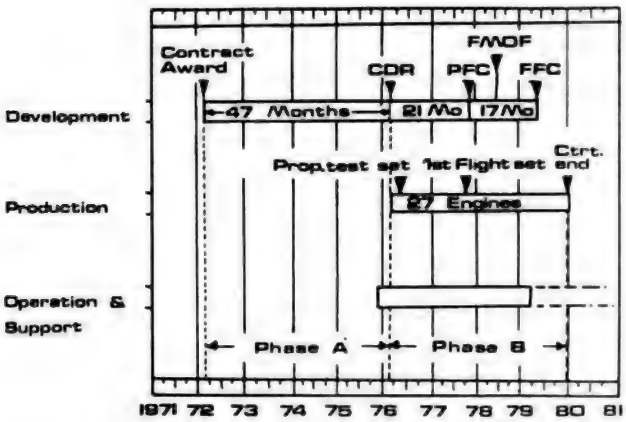


Fig. 2. Space Shuttle Main Engine: Development and production schedule.

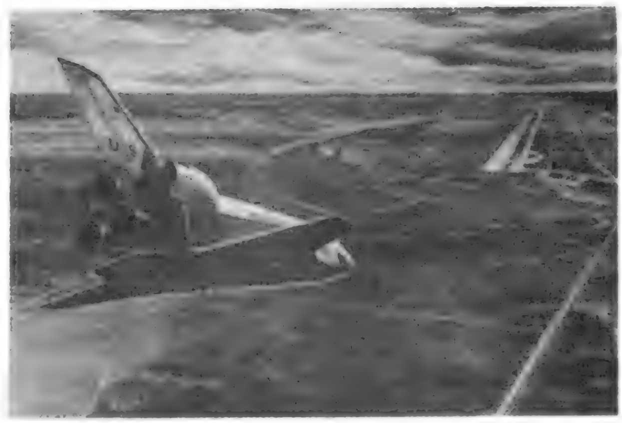


Fig. 3. Artist's impression of the Orbiter returning to land on the runway at the Kennedy Space Center clearly shows the three large SSME's and the two subsidiary OME's.

Manned Orbital Flight (FMOF), following 12 months after PFC, will verify SSME performance in actual mission conditions. If these milestones are passed without revealing any significant defects in design or manufacture, the engine will receive its Final Flight Certificate (FFC) after a further 5 months, in April 1979. By this time at least two flight models of each component will have notched up the full 7.5 hours firing, with at least 55 starts. The remaining flight engines will then be delivered to be installed in other Shuttle Orbiters.

The Engine

The Space Shuttle is centred around the Orbiter, an aeroplane-like vehicle about the same length as a Boeing 747, longer than the Wright brothers' first flight. This is mounted on a huge external propellent tank, 51 m long; and two Solid Rocket Motors (SRM's, see *Spaceflight* January '73 p. 15). There are 3 SSME's on each Orbiter (see photo *Spaceflight* August '73 p. 313) which are canted away from the vertical, towards the tail, since they are well out of the plane

Fig. 4. *(Right)* Flow diagram of the Space Shuttle Main Engine shows the path of liquid oxygen and liquid hydrogen. The low pressure turbopumps are at the top, above the two high pressure turbopumps. Hydrogen is shown flowing through the wall of the engine bell and other components.

Rocketdyne Division Rockwell International

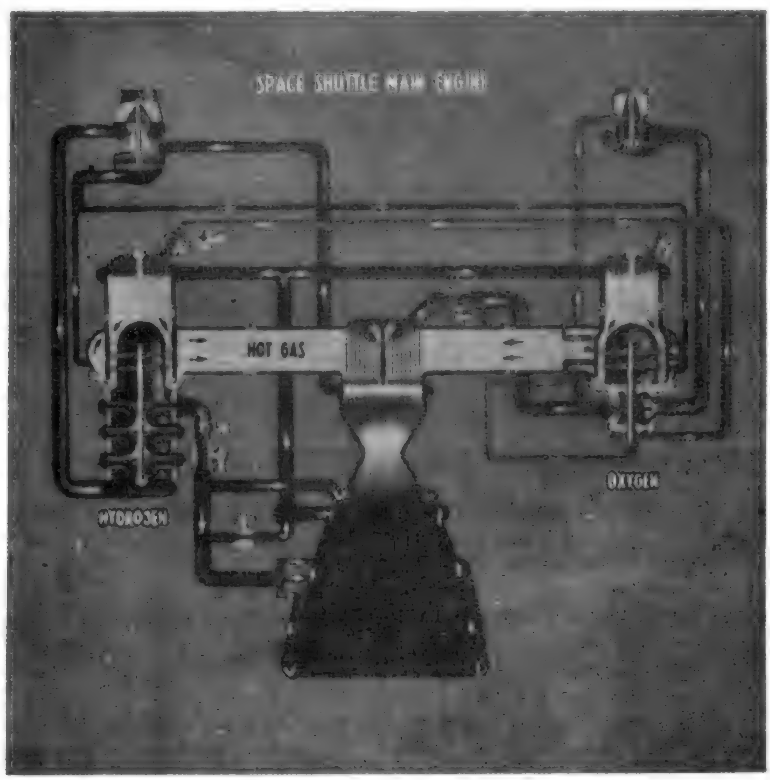


Fig. 1. Space Shuttle Main Engine. *(Left)* In the exploded view, the Pre-burner Assembly is ringed and the Controller, low pressure turbopumps and other major components are omitted. The details are seen from roughly the same angle.

Copyright drawing by Robert Edgar

Fig. 5. The Santa Susana Test Facility, scene of recent tests of the Space Shuttle Main Engine, during its conversion from an S-II to an SSME static test site.

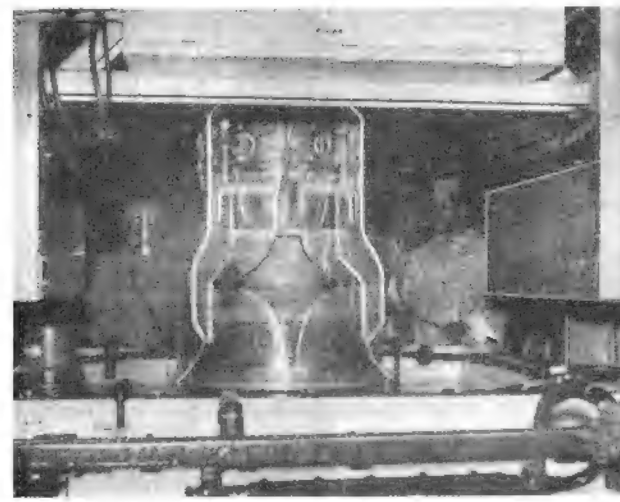


Fig. 6. First flight-type version of the Space Shuttle Main Engine's combustion chamber is sprayed with water between coatings of nickel.

Fig. 7. A short burst of fire from the SSME's preburner assembly ushers in the test phase of engine development.

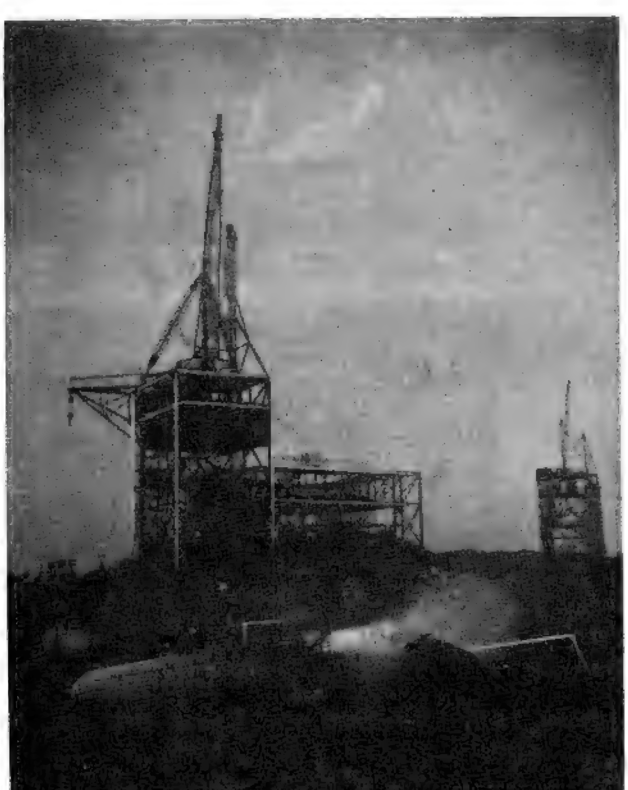
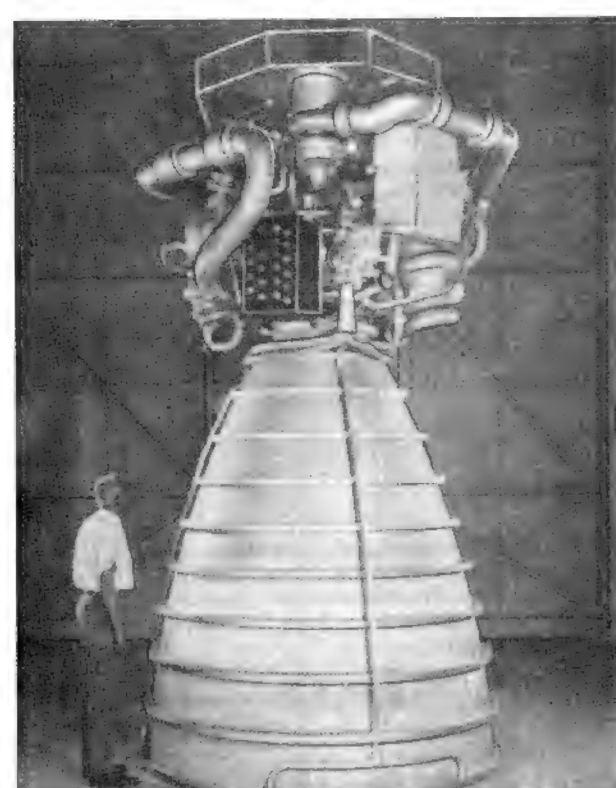


Fig. 8. Engineering mockup of the SSME built by Rocketdyne to prove the basic design features.



Space Shuttle Main Engine (SSME) Characteristics (March 1974).

Thrust		
Sea Level	375,000 lbf	1,680,000 N
Vacuum	470,000 lbf	2,155,600 N
Chamber Pressure	2970 psia	20,700,000 Nm^{-2}
Area Ratio	77.5	
Specific Impulse		
Sea Level	363.2 sec.	
Vacuum	455.2 sec.	
Mixture Ratio	6.0	
Propellents		
Fuel	Liquid hydrogen	
Oxidiser	Liquid oxygen	
Length	167 in.	4.6 m
Bell Diameter	74 in.	2.6 m
Life (without overhaul)	7.5 hours 100 starts	

Fig. 9. The SSME fuel injector, which mixes oxygen and hydrogen gases and forces them into the combustion chamber, being assembled at Rocketdyne in preparation for a test late last summer.

All photos Rocketdyne Division Rockwell International

of the Shuttle's centre of gravity. With the discarding of the external tank they are gimballed nearer to the flight vector by a continuous control system. Each SSME develops 470,000 lbf vacuum thrust, reduced to 375,000 lbf at sea level, and providing a total of 1.41 million lbf in vacuum. During the beginning of the 8 minute launch phase they assist the two SRM's, which together produce an additional 4.3 million pounds of thrust until, 125 seconds after ignition, the solid-propellent boosters are parachuted to an ocean recovery. The SSME's are not used in orbit, two smaller OME's (Orbital Manoeuvring Engines) take over after tank jettison to establish the Orbiter in the initial elliptical orbit, provide thrust for the subsequent circularisation at 150 n.m. altitude and finally deorbit the vehicle.

In size the SSME resembles the familiar J-2 engine used in the upper two stages of the Saturn V launch vehicle (being 4.6 m long and 2.6 m across the engine bell) but posed much stiffer design problems. Firstly, to achieve the high thrust and efficiency demanded of the engine, a very high pressure is required in the combustion chamber: 2970 psia, some five times the value of contemporary engines. Equally critical, it must endure 55 flights (the 7.5 hours operation mentioned earlier) with no more than routine maintenance; all major components have to be easily accessible without the necessity for removing an engine. In addition the engine must be throttlable and steerable, the latter requiring a hydraulically-operated gimbal mounting. To handle the complex operation of the engine a Honeywell digital computer ('the Controller') is attached to the piping surrounding the combustion chamber, as shown in Fig. 1. Maintenance data acquisition is also handled by this computer.

The engine is fuelled by liquid hydrogen (LH_2) which is burned with liquid oxygen (LO_2 or LOX), carried in the external tank, and used in a mixture ratio of ($LH_2 : LO_2$) 6:1. To demonstrate the workings of the engine, in somewhat simplified form, I shall describe the passage of the propellents through its components.

The liquid oxygen first enters the Low-Pressure Oxygen Turbopump (LPOT) which drives the bulk of it to the High Pressure Oxygen Turbopump (HPOT). The remainder is impelled to the oxidiser preburner, mounted on top of the HPOT, which supplies hot gas to drive the two high pressure turbopumps, the HPOT and the corresponding one for the hydrogen fuel. The oxygen high-pressure turbopump, powered by the oxidiser itself, sends the LO_2 into the Hot Gas Manifold (HGM), which efficiently mixes the two propellents and passes them into the combustion chamber where they are burnt, and expand 77 times.

An entirely new metal alloy and forging technique had to be developed to fabricate a combustion chamber that could cope with the stressful environment of high pressure and temperature, about 550°C (1000°F). Rocketdyne came up with NARloy-Z (from North American Rockwell. as Rockwell International was known), composed of Silver (2.75 - 3.25%), Zirconium (0.35 - 0.55%) and the remainder Copper. It combined moderate strength with good fatigue resistance, long life and high thermal conductivity – all essential properties hard to find combined in other metals.

The liquid hydrogen follows a similar route (Low Pressure Hydrogen Turbopump to High Pressure Hydrogen Turbopump & Preburber, and from there to the combustion chamber *via* the HGM) with one major difference. Some of the fuel is diverted from its route to the HGM to travel through the walls of the engine bell and other equipment items for

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THE ATLAS-CENTAUR

By Mike Howard

Introduction

Introduced in the late 1950's as part of the United States' Intercontinental Ballistic Missile (ICBM) programme the Atlas vehicle has since become one of the most familiar and certainly most launched space boosters. Over 500 of these vehicles were built by the General Dynamics' Convair Aerospace Division in San Diego and more than 400 launches have been carried out for a large variety of missions both by NASA and the USAF.

Atlas was in many respects an entirely new concept in launch vehicle technology; to quote Mel Barlow, General Dynamics' manager of advanced space programmes; "Every other launch vehicle in use today draws upon technology that was established by Atlas in such areas as swivelling or gimballed engines for stabilization and directional control, integral pressure-stabilized propellent tanks, separable nose cones and all-inertial guidance."

Three years after Atlas, General Dynamics introduced the Centaur booster to add greater flexibility to space operations. Although Centaur vehicles are now being used in conjunction with the Titan III-E booster [1] their major achievements to date have been with the Atlas vehicle.

Atlas' History

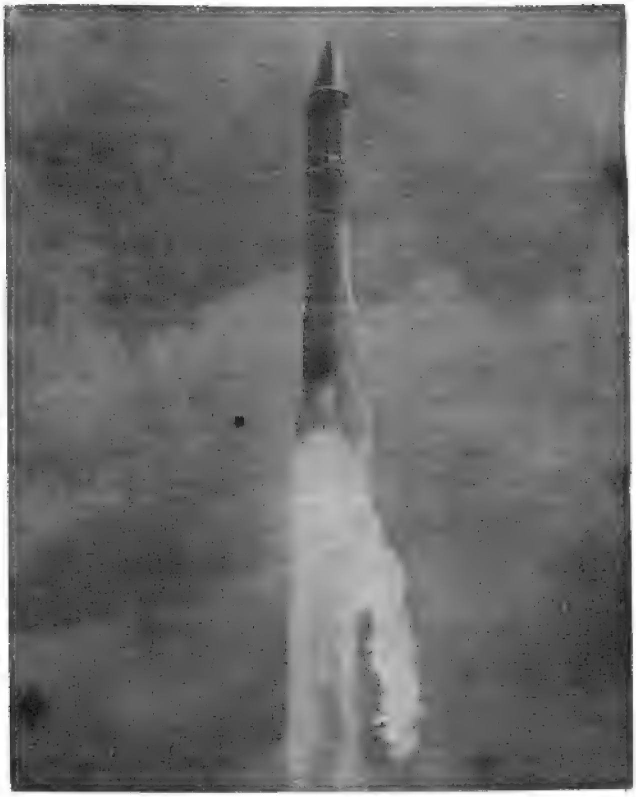
Development of the Atlas began in the Spring of 1946, shortly after the close of World War II, as the vehicle which would be capable of delivering a 5,000-lb. warhead to a trans-Atlantic target. Under the name of project MX-774 the concept slowly began to take shape. After several years of somewhat hesitant progress due in great degree to pinch-penny funding, the U.S. Air Force suddenly decided that Atlas was an urgent requirement. Thus, by the end of 1954, detailed design began of a missile 108 ft. long and 12 ft. in diameter with a 656,000 lb. liftoff thrust capable of delivering a 7,000 lb. payload to a target 5,500 miles away. The vehicle dimensions were later to be amended to 75 ft. length, including payload, and 10 ft. diameter.

On 11 June 1957 the first Atlas lifted off but was only partially successful as was the second attempt four months later. Complete success came with the third launch on 17 December 1957; Atlas was in business.

The Atlas programme had received further stimulus when on 4 October 1957 the Soviet Union placed its 184-lb. Sputnik 1 into orbit. With this blow to national prestige the United States accelerated its own satellite programme. On 18 December 1958 an Atlas vehicle placed the first active communications satellite known as Project Score into orbit. For 13 days the 18-lb. spacecraft transmitted taped messages back to Earth including President Eisenhower's historic Christmas greeting.

More "firsts" for the Atlas vehicle followed. In May 1960 an Atlas set a world record for ICBM flights when it climbed to an altitude of 1,000 miles and travelled almost 10,000 miles. As part of the Mercury programme an Atlas booster sent the chimp, Enos, on a 2-orbit flight around the Earth on 29 November 1961 followed on 20 February 1962 by the first United States manned orbital flight, Mercury 6, carrying Colonel John H. Glenn on a 3-orbit mission. During the next 8 months Atlas vehicles successfully launched three more astronauts to complete Project Mercury.

Since the early 1960's Atlas vehicles have scored many further successes as an independent booster and in combination with an Agena upper stage. Atlas-Agenas became an integral part of the manned Gemini programme during the orbital rendezvous and docking missions with the Agena acting as "target". As unmanned precursors to the manned lunar Apollo programme, Ranger and Lunar Orbiter spacecraft were launched by Atlas-Agenas. Early Mariner missions to Venus and Mars also owe their success to Atlas-Agena boosters. However, although this combination was very popular during the 1960's its payload was limited to 575 lb. With spacecraft becoming heavier it became necessary to use a new combination, which led to the Atlas-Centaur. It is this combination that has been used most frequently during recent years for interplanetary missions.



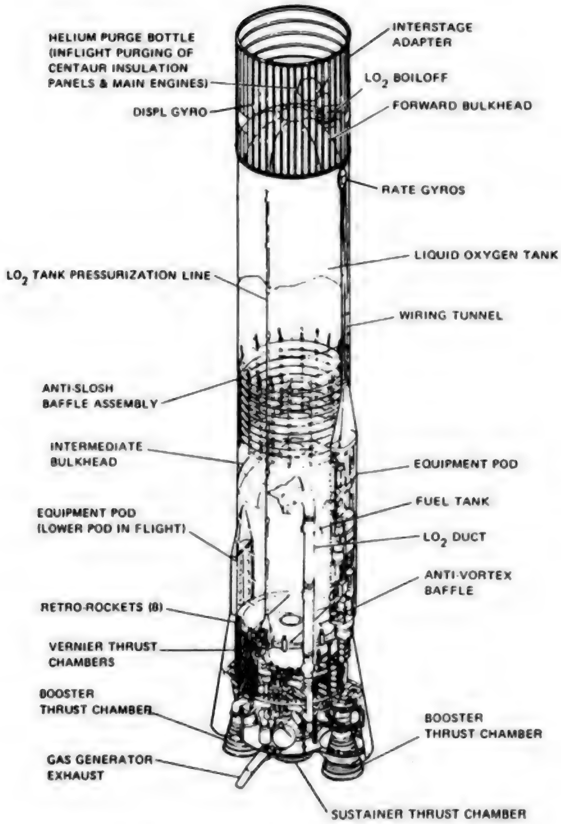
Atlas-Centaur lift-off at the Kennedy Space Center.

General Dynamics Convair Division

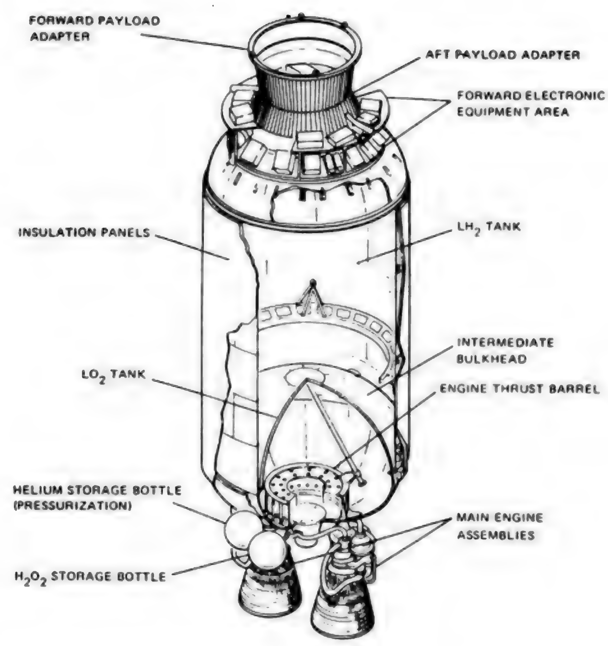
Centaur's History

When Russia launched Sputnik 1 in October 1957 the U.S. decided that a more powerful upper stage would be required to supplement the liftoff power of the still secret Atlas ICBM. To fulfil this requirement Convair proposed a liquid hydrogen and liquid oxygen second stage vehicle for mounting on the Atlas.

This combination of hydrogen and oxygen can produce 40 per cent more power than conventional propellents. In November 1958 the U.S. government awarded General Dynamics the Centaur contract. NASA took control of the Centaur programme from the Air Force shortly after its establishment in 1959 and on 8 May 1961 the prototype was on the launch pad. Fifty-five seconds after lifting off from Cape Canaveral the vehicle disintegrated in a fireball. After



Atlas SLV-3C Vehicle (First Stage).



Centaur Vehicle (Second Stage).

this initial failure the second test launch in late 1963 was an unbounded success and by mid-1965 Centaur was declared fully operational.

Atlas/Centaur's History

Atlas-Centaur's first major mission came with the launch of the Surveyor 1 lunar soft-lander on 30 May 1966. Over the next 2 years six more Surveyor spacecraft were launched to the Moon to return almost 88,000 photographs from 5 successful missions. On 7 December 1968 an Atlas-Centaur placed the first successful Orbiting Astronomical Observatory into orbit to study stars in UV, IR, gamma and X-ray using 11 telescopes. After a failure during the launch of Applications Technology Satellite (ATS) 4 in 1968, Atlas-Centaur successfully placed ATS-5 into a geo-stationary orbit on 12 August 1969.

Since launching Mariner 6 on 24 February 1969 Atlas-Centaur has successfully boosted 3 other Mariner craft on interplanetary trajectories. Mariners 6 and 7 were fly-by missions to Mars which returned a total of 201 pictures. On 30 May 1971 Mariner 9 lifted off and six months later swung into orbit around the Red Planet. Over the next 11½ months the spacecraft proceeded to photograph the whole of the planet's surface returning 7,329 pictures. Spacecraft controllers eventually switched off Mariner's transmitter by remote command on 27 October 1972.

The most recent, and still continuing, Mariner mission was launched by Atlas-Centaur on 3 November 1973. Mariner 10 was destined to become history's first dual-planet spacecraft and the first to use the gravity assist/trajectory deflection technique. After swinging by Venus on 5 February 1974 Mariner continued *en route* to Mercury which it successfully encountered on 29 March. The spacecraft is now in a heliocentric orbit which enables it to re-encounter Mercury every six months.

Atlas-Centaur vehicles have also been used in the exploration of the giant planet, Jupiter. Launched on 3 March 1972 Pioneer 10 spent 21 months crossing 620 million miles of space to encounter Jupiter on 3 December 1973. Early in 1973 a second spacecraft, Pioneer 11, had set off on a similar journey. Pioneer 11 swung past Jupiter in December 1974 and is now heading across the Solar System to encounter Saturn in September 1979.

In 1971 an Atlas-Centaur vehicle launched the first Intelsat 4 communications satellite for the Intelsat consortium.

Atlas-Centaur vehicles are at present launched from Complex 36 at the John F. Kennedy Space Center, Florida. Prime contractor for Atlas-Centaur is General Dynamics' Convair Aerospace Division in San Diego, California with NASA programme management under the control of the Lewis Research Center at Cleveland, Ohio.

Vehicle Description

The Atlas-Centaur can place 9,900 lb. (4,500 kg) into a 345-mile (640-km) orbit, or 4,000 lb. (1,810 kg) into a synchronous transfer orbit.

The vehicle has the following characteristics:

[Concluded on page 80

SATELLITE DIGEST – 79

A monthly listing of all known artificial satellites and spacecraft, compiled by Robert D. Christy. Information is based on that supplied by the Space Department of the Royal Aircraft Establishment, Farnborough and other sources. For information on the derivation of orbital parameters, abbreviations, etc., see July 1972 issue, p. 262.

Continued from January issue, p. 35.

Name, designation	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclination (deg)	Nodal period (min)	Launch centre, launch vehicle and payload/launch origin
Cosmos 670 1974-61A	1974 Aug 6.01 3.0 days (R) 1974 Aug 9.0	Sphere-cylinder 4000?	5 long? 2 dia?	211	294	50.55	89.48	Tyuratam-Baikonur USSR/USSR
Cosmos 671 1974-62A	1974 Aug 7.54 12.7 days (R) 1974 Aug 20.2	Sphere-cylinder 4000?	5 long? 2 dia	182 169	353 312	62.82 62.82	89.84 89.30	Plesetsk USSR/USSR (1)
1974-62C	1974 Aug 7.54 33 days 1974 Sep 9	Sphere?	2 dia?	163	302	62.81	89.14	Plesetsk USSR/USSR (2)
1974-63A	1974 Aug 9.14 80 years	12 sided frustum 195	1.64 long 1.31 max.dia. 1.10 min.dia.	806	875	98.86	101.76	WTR Thor Burner 2 DoD/USAF
Cosmos 672 1974-64A	1974 Aug 12.27 5.9 days (R) 1974 Aug 18.2	Sphere + cone-cylinder + 2 wings + antennae, 6570?	7.5 long 2.2 dia	195 227	221 238	51.76 51.76	88.59 89.09	Tyuratam-Baikonur Soyuz USSR/USSR (3)
1974-65A	1974 Aug 14.66 1 month?	Cylinder 3000?	8 long? 1.5 dia	135	402	110.51	89.89	WTR Titan 3B/Agena D DoD/USAF
Cosmos 673 1974-66A	1974 Aug 16.16 60 years	Cylinder + 2 vanes	5 long? 1.5 dia?	607	637	81.21	97.17	Plesetsk USSR/USSR
Soyuz 15 1974-67A	1974 Aug 26.83 2.01 days (R) 1974 Aug 28.84	Sphere + cone-cylinder + antennae 6600?	7.5 long 2.2 dia	173 251	236 271	51.62 51.60	88.52 89.67	Tyuratam-Baikonur Soyuz USSR/USSR (4)
Cosmos 674 1974-68A	1974 Aug 29.32 8.9 days (R) 1974 Sep 7.2	Sphere-cylinder 4000?	5 long? 2 dia?	175	323	64.99	89.48	Tyuratam-Baikonur USSR/USSR
1974-68C	1974 Aug 29.32 16 days 1974 Sep 14	Sphere?	2 dia?	174	307	64.99	89.31	Tyuratam-Baikonur USSR/USSR
Cosmos 675 1974-69A	1974 Aug 29.62 5000 years			1365	1426	74.04	113.70	Plesetsk USSR/USSR
ANS 1 1974-70A	1974 Aug 30.59 2½ years	Box + 2 panels 129	1.23 long 0.61 wide	258	1173	98.03	99.13	WTR Scout Netherlands/NASA (5)

Supplementary Notes:

(1) Orbital data at 1974 Aug 8.1 and 1974 Aug 9.1.
(2) Ejected from 1974-62A during 1974 Aug 19.
(3) Orbital data at 1974 Aug 12.5 and 1974 Aug 14.5.
(4) Second attempt to place a crew aboard the Salyut 3 space station. The attempt ended in failure after several unsuccessful docking attempts; the landing took place in darkness. The crew consisted of Lt.Col. Gennady Sarafanov and Col. Lev Demin.
(5) First Netherlands satellite, designed to study ultraviolet radiation and X-ray sources. Launch was delayed for three days by problems during the countdown. The launch vehicle then failed to achieve the planned 500 km circular orbit but it is hoped to obtain useful data over a six month period.

CETI SIGNAL/*Concluded from p. 54*

Although a reply to the signal could not be received from Messier 13 for at least 48,000 years, it is interesting to speculate if an unknown stellar community in the path of the signal may pick up the 'message' and transmit a reply somewhat earlier than expected.

Undoubtedly there will be more CETI signalling experiments and it is to be hoped that further work of this kind will be the subject of international agreement.

Later programmes may include "tuning in" to globular clusters to discover if coherent signals, characteristic of "intelligence", can be deduced from naturally-induced background radiation.

BOOK REVIEWS

Edited by L. J. Carter

The Stars in their Courses
By Isaac Asimov, White Lion Publishers, 1974, pp. 199, £2.25.

If you know anyone who discounts the importance of science, give them this or any other collection of factual Asimov, articles originally appearing in the *Magazine of Fantasy & Science Fiction* . This particular selection covers the period 1969/70. The topics are wide-ranging, Astronomy, Physics, Chemistry and Sociology – yes, he can write with authority about that too! I only wish I had had a science teacher like him. So many fail to breathe life into their subject, but Dr. Asimov who teaches Biochemistry at Boston University is never dull; every word is packed with meaning and interest. Does he allow his vigil to weaken for instance on p. 28, where he quotes the astronauts of "Luna 11" landing on the edge of Mare Tranquillitatis, or was that deliberate to make us sit up and take notice? His philosophy of learning is touched upon in this article on lunar nomenclature written four days after the death of his father, a man who had been born before the advent of controlled flight in the atmosphere, and who had lived to see Apollo 11. With the wit of a latter day Voltaire but without malice, Dr. Asimov demolishes Velikovsky's theories and the current fad for pseudo-science and astrology. I particularly like his description of the latter's characteristic quality as resembling the "excrement of the male bovine!"

In the middle chapters, commencing the elementary subjects of mass and weight, he progresses through Cavendish and Newton to a discussion of gravitation. Eloquent where necessary, he even indicates the points which have to be modified in the light of Einstein. Most BIS members love fooling about with the effects of relativistic velocities, and I am no exception. The Doppler-Fizeau effect and measurement of astronomical distances are subjects that we never tire of.

Passing to the field of Chemistry he gives a good account of the discovery of the rare Earth elements and the periodic table, and how no Nobel Prize was awarded in 1916. If it had been, the brilliant Englishman Moseley would have been a firm candidate for his concept of atomic number; finally cleaning up the periodic table and laying foundations for future progress in all fields. Tragically, Moseley was a victim of the "War to end all wars".

Somewhat surprisingly, I found the Sociology section of the book by far the most interesting. Asimov shows a depth of feeling for his fellow men that does him great credit. Citing Franklin's lightning experiment as the turning point between superstition and reason, he goes on to the idea of original sin in science. Can there be such a thing? He thinks so, and he names the man responsible. In my opinion, what was unleashed remains a more terrible threat to civilisation than nuclear attack. Is it a coincidence that after this article first appeared, the President of the United States announced the abandonment of biological warfare? The last two chapters offer some of the shrewdest comments on population that I have ever read. Of course this little planet has enough oxygen, water, food and resources, but there are too many people, a situation which leads to human degradation and worse. (I am particularly conscious of this as I write, with heavy traffic from London's docks streaming by outside!). We must adjust to a finite world. There are no longer national or international problems; just problems. This has been the thought of responsible men since Apollo 8. I wish that these chapters could be delivered in the form of an address to the United Nations, that all would attend and that Divine intervention should decree continuous session until the problem is solved! The opening up of the American West which cemented the Union, is given as an example of how all nations could be united against a common frontier. Since Man is by nature agressive, he must become Planetary Man and go forward to conquer Space. If it does happen, the space effort whatever its cost short of world bankruptcy, will have been worthwhile.

Good books like great explorers only open up the subject, not giving all the answers but leaving room for others to follow. This is just such a book.

A. M. NIXON

Carrying the Fire, An Astronaut's Journeys
By Michael Collins. With a foreward by Charles A. Lindbergh, Farrar, Straus, and Giroux, New York, pp. 478, $10.

This is the first candid book about life as an astronaut. It is not written by a moonwalker, but by a man who got no closer to the lunar surface than 60 miles, a distance, he feels, that gave him a better perspective of man's first steps on the Moon.

Michael Collins was the command module pilot of Apollo 11, the forgotten astronaut who orbited the Moon while Neil Armstrong made a "giant leap for mankind" on the lunar surface.

Carrying the Fire is very light on the technical side. Despite his intimate involvement with jets and spacecraft, Collins does not love machinery. He is also a man who bores easily, he says, and wrote for those who bore easily. The reader can start with any chapter of *Fire* and not be lost. His style is relaxed, as though he was in his den discussing the flight.

About 12 other books have been written by astronauts, including one for children and one of poems. The "official" story of Apollo 11 and its crew was *First on the Moon*, written by the late Gene Farmer and Dora Jane Hamblin under the somewhat infamous Time-Life/Field Enterprises contract that excluded the rest of the media from the astronauts' homes.

Four astronauts have since broken the official mould: Brian O'Leary's *The Making of an Ex-Astronaut*, an acidic look at astronaut selection and flight assignments, Jim Irwin's *To Rule the Night*, an Apollo 15 astronaut's religious odyssey, and Buzz Aldrin's *Return to Earth*, the second man-on-the-Moon and his voyage through mental depression, and Collins' book. (Neil Armstrong has secluded himself from the world – it is not known if he is working on a book).

Collins is candid in evaluating other astronauts:. He says Wally Schirra (Mercury-Sigma 7, Gemini 6, Apollo 7) "could make a good living playing Santa Claus", Al Shepard (Mercury-Freedom 7, Apollo 14) is easily the "shrewdest of the bunch", Frank Borman (Gemini 7, Apollo 8) "makes decisions faster than anyone I have ever met", Rusty Schweikart (Apollo 9) is "mildly nonconformist", and Pete Conrad (Gemini 6 and 9, Apollo 12, Skylab 1) is "one of the few who lives up to the image".

Of the three Apollo 11 crewmen, he says: Neil Armstrong "is a classy guy, and I can't off-hand think of a better choice to be first man on the Moon. "Buzz Aldrin "I think resents not being first on the Moon more than he appreciates being second", and Mike Collins is "Lazy (in this group of overachievers, at least), ... generally good judgement and a

broader point of view than most".

These appraisals merely show that beneath the space agency's PR image, the astronauts are human beings.

Collins' seat on the Apollo 11 mission was the result of bad luck and schedules that were juggled both before and after the spacecraft fire that killed the Apollo 1 crew. When the spacecraft 014 mission, for which he was backup Lunar Module pilot, was cancelled, and crews reassigned, Collins was "promoted" to Command Module pilot on what became the Apollo 8 mission, man's first flight around the Moon. He soon lost that seat when he developed a painful bone spur in his neck that was gradually paralyzing him. After recovering from corrective surgery, he was slipped into the Apollo 11 crew.

Had he stayed in the space programme, Collins estimates, he would have been backup commander for Apollo 14, and prime commander for Apollo 17, placing him on the Moon with the last Apollo mission. But that meant another year (which became three) of training while his family became strangers. Before Apollo 11 left Earth, Collins had decided it was his last flight. After leaving NASA, he became Assistant Secretary for Public Affairs of the State Department, a post he did not feel suited for. He is now director of the National Air & Space Museum, and his office is in the same building as the Wright Flyer, the Spirit of St. Louis, and the Apollo 11 Command Module, Columbia.

Of space flight itself, Collins almost gives the impression that it is a release from countless hours in simulators that nearly turn astronauts into extensions of the spacecraft. But his joy in flight is real, and the training just an obstacle to overcome.

He also reveals a number of minor worries and an occasional racy thought: did the little old ladies who glued the space suits together glue it all, will a digit be dropped in punching up computer instructions for entering lunar orbit (even though the computer gave the right directions, he still had to look out the window to make sure Apollo 11 was pointed in the right direction). He shares with other astronauts a dislike for the conservatism of NASA doctors and the monotonous questions asked by reporters. He savours, briefly, the thought of commanding a spaceship crewed by 1000 weightless, braless beauties ("it is Saturday morning, naturally, and time to inspect the crew").

A handful of oddities emerge, too. While saying little about the crew's round-the-world trip, he enumerates some of the royalty who hosted them and ignores the elected heads of state who hosted them. He does not mention the moustache he sprouted during the Moon trip. Before waxing poetic and talking about the profound effect that might occur if world leaders saw the Earth from space, he implies a dislike of "campus hairies", many of whom worked for non-violence. Little is said of his family, only that whenever possible he left the simulators for them. Mike Collins, astronaut, speaks eloquently, but Mike Collins, private citizen, remains silent. *Fire* covers only his career as a test pilot and an astronaut.

The one thing that he found most impressive about viewing the Earth from lunar orbit is the fragility of our home, especially when compared to the Moon: "But from space there is no hint of ruggedness to it; smooth as a billiard ball, it seems delicately poised on its circular journey around the Sun, and above all it seems fragile ... Is the sea water clean enough to pour over your head, or is there a glaze of oil on its surface? ... Is the riverbank a delight or an obscenity? The difference between a blue-and-white planet and a black-and-brown one is delicate indeed".

He also saw the Moon in a different perspective: "The Moon I have known all my life, that two-dimensional, small yellow disk in the sky, has gone away somewhere to be replaced by the most awesome sphere I have ever seen".

This is the astronaut's biography that everyone has waited for. In it Collins answers, with more success than others. "What was it really like up there?" In it we see the pilot as a poet-philosopher. He places us in the acceleration couch, hurls us around the Moon and back, and imparts to us some of the cosmic perspective that only a Moon man can have.

DAVE DOOLING

Cosmology Now
Ed. Laurie John, BBC, 1973, pp. 168, £2.75.

The sixties was a decisive decade for cosmology. As a science, cosmology had been fairly stagnant since the 1920's when the expansion of the Universe was discovered. Then, in the late fifties and early sixties, radio astronomers found evidence for an evolving universe. The cosmic microwave background, considered to be the remnant of the early hot phases of the "Big Bang", was first detected in 1965. Quasars, which, if their redshifts are to be interpreted as cosmological, are the most distant objects known, were found in the early sixties. Most of these and other new observations fitted into the Hot Big Bang theory of the Universe and it is timely that the present situation should be reviewed.

What was originally a series of Radio 3 talks has been expanded into a number of individual essays. Peach and Sciama discuss the background and content of the main cosmological models so far proposed, with Narlikar putting in some comments for the Steady State theory. Ryle emphasises the need to observe the Sky over as wide a wavelength band as possible and Lynden-Bell puts forward current ideas on the sources of cosmic power, such as where quasars might get their energy from. Rees looks into the crystal ball and sets out the various end points that may be the fate of the Universe as we know it. There is also a topical addition by Penrose on Black Holes, which provides one of the few recommendable essays on that subject anywhere.

It is rare to find such a readable collection of essays by leaders in their field in any one book. The reader may find that several topics such as the Big Bang, and the white dwarf, neutron star, black hole sequence are discussed four or five times in all. However, this need not be a drawback, as a clearer understanding often results from many viewpoints. Laurie John and the BBC are to be congratulated on a high standard of science journalism.

DR. A. C. FABIAN

An Introduction to Astronomy
By L. W. Fredrick and R. H. Baker, Van Nostrand Reinhold, 1974, pp. 454, £5.85.

The 8th Edition of this famous standard work, now with paper covers, will be a welcome addition to any student's study. The text is clear, authoritative, and well-illustrated with numerous line drawings and photographs. Questions and references for further reading follow each chapter.

British 'First' in Planetary Exploration

Sir, Your article on the 1978 missions to Venus (Space Report, 10 October 1974) mentions the French and German scientists who are involved but overlooks a major British contribution.

The Department of Atmospheric Physics at Oxford University is cooperating with the Jet Propulsion Laboratory in Pasadena, California, to produce an infrared remote sensing experiment which will measure the vertical temperature structure of the Venus atmosphere from the orbiter. Although remote sounding of the Earth's atmosphere for weather forecasting purposes is now routine, this will be the first time Venus has been explored in this way.

We plan to compare the major weather systems in the upper atmosphere of Venus with those of the Earth, and to discover the origin of the very high wind speeds which have been observed in ultraviolet photographs of the cloud patterns on the planet. The British group will be building an important part of the hardware, which will be brought to Pasadena for integration with the rest of the instrument. We plan to use a direct link across the Atlantic to move the incoming data from Venus to Oxford in quasireal time, for analysis at the Clarendon Laboratory.

This is an important first in planetary exploration for Britain, which should give the members of the B.I.S. some occasion for pride.

F. W. TAYLOR

CSE Astronautics Course?

Sir, I would like to introduce a C.S.E. Astronautics course. If any other teacher-members of B.I.S. are interested in helping formulate an appropriate syllabus, then I would be glad to hear from them.

I envisage the course content being historical in nature, not technical.

STIRLING DUTTON
45, Lidgett Park Court, Roundhay, Leeds 8

OBITUARIES

DOUGLAS BRADLEY, 57, (Fellow), for many years a draughtsman with Ferranti Ltd.

DONOVAN HILTON RAWCLIFFE, 56, (Member), a self-employed writer with an interest in astronomy and philosophy.

RONALD JOHN SHEPPEY, 48, (Associate Fellow), Chief Designer with Clare Construction Ltd.

CHRISTOPHER WILLSON, 55, (Senior Member), previously employed with the deHavilland Aircraft Co. Ltd., and who subsequently emigrated to Australia.

PRIME POWER FOR THE SHUTTLE

Concluded from page 73]

purpose of cooling to near-ambient temperatures. The system is known as regenerative cooling. However, unlike other engines employing this technique (the F-1 for example), all fuel used in this way is eventually burnt in the combustion chamber as is the propellent used in the preburners not jettisoned, another new feature.

Acknowledgement

The author wishes to extend his grateful thanks to the public affairs staff of the National Aeronautics & Space Administration and, particularly, to the Space and Rocketdyne divisions of the Rockwell International Corporation, for material used in this article.

THE ATLAS-CENTAUR

Concluded from page 75]

Height: 117.4 ft. (35.8 m)

Maximum Diameter: 10 ft. (3.04 m)

Atlas – Propellent comprises liquid oxygen and modified kerosene (LOX/RP-1); thrust, 403,000-431,000 lb.

Centaur – Propellent comprises liquid oxygen and liquid hydrogen (LOX/LH_2); thrust, 30,000 lb.

Atlas/Centaur's Future

In addition to launching the upcoming Intelsat communications satellites, Atlas Centaur vehicles are scheduled to boost NASA's first three High Energy Astronomical Observatory (HEAO) spacecraft into low orbit circular Earth orbits between 1977 and 1979. [Later versions of the HEAO spacecraft will be placed into orbit by the Space Shuttle. Ed.]. Future missions will see the Centaur vehicle being used more and more in conjunction with the Titan III-E launch vehicle. This latter configuration will be used for two U.S.-West German Helios solar spacecraft, two 1976 Viking Mars landers, and two Mariner spacecraft on fly-by missions to Jupiter and Saturn later in the decade.

After spearheading America's space effort in the 1960's the Atlas vehicle now appears to be entering the twilight of its life. As spacecraft payloads grow, missions that, in the past, would have used an Atlas are turning to the more powerful Titan III series of launch vehicles, and yet whatever the future may hold the technology created for Atlas goes on. The designers can take pride in the fact that a vehicle created for war has served the peaceful exploration of space so expeditiously for so long.

Acknowledgement

The writer wishes to thank the Western Region Public Affairs Office of General Dynamics for their assistance in the preparation of this article.

REFERENCE

1. M. W. Howard, Titan III-E Centaur, *Spaceflight*, July 1974, pp. 277-278.

Spaceflight

Spaceflight is published monthly for the members of the British Interplanetary Society.

Full particulars of membership may be obtained from the Executive Secretary at the Society's offices at 12, Bessborough Gardens, London, SW1V 2JJ: Tel: 01-828 9371.

Correspondence and manuscripts intended for publication should be addressed to the Editor at 12, Bessborough Gardens, London, SW1V 2JJ.

Opinions in signed articles are those of contributors, and do not necessarily reflect the views of the Editor or the Council of the British Interplanetary Society, unless such is expressly stated to be the case.

Members who would like to present papers to General Meetings, Main Meetings, or contribute to Space Study Meetings, are invited to write to the Executive Secretary, British Interplanetary Society, 12, Bessborough Gardens, London, SW1V 2JJ.

Symposium
Theme **STARSHIP STUDY REPORT**
To be held in the Tudor Room, Caxton Hall, Caxton Street, London, S.W.1. on **26 February 1975,** 6.30-8.00 p.m.
Reports will be presented on various aspects of the Starship Study by members of the Daedalus team.

Admission tickets are not required. Members may introduce guests.

Film Show
A Programme of New Films on the theme of **SKYLAB** will be held in the Botany Lecture Theatre, University College, Gower Street, London, W.C.1. on **11 March 1975,** 6.30-8.30 p.m.

The Programme will be as follows:-
(a) Skylab: The Search & The Hope
(b) Skylab: Mission Made Possible
(c) Skylab: The Second Journey
(d) Spaceship Skylab: Wings of Discovery

Admission tickets are not required. Members may introduce guests.

Space Study Meeting
Theme **THE VIKING PROGRAMME** by P. J. Parker.
To be held in the Kent Room, Caxton Hall, Caxton Street, London, S.W.1. on **4 April 1975,** 6.30-8.30 p.m.

Admission tickets are not required. Members may introduce guests.

Main Meeting
Theme **EUROPEAN PARTICIPATION IN EARTH RESOURCES (SPACE) PROJECTS**
(To consider National, ESRO/ESA activities in relation to ERTS-1, Skylark, Skylab, ERTS-B, etc.).
To be held in the Large Physics Lecture Theatre, University College, Gower Street, London, W.C.1. on **9 April 1975** *(All day).*

Papers offered to date are as follows:-
1. Potential Applications of Space Image Analyses and the Development of Natural Resources, by Dr. D. Bannert
2. Coordination of Remote Sensing Objectives, by S. R. Dauncey
3. Comparison of the Utility of Alternative Camera, Film & Filter combinations for Space Photography from the Skylark Earth Resources Rocket, by Dr. J. R. Hardy
4. Attitude Control of Earth Resources Rockets by an RF Interferometric Sensor, by Dr. G. Mayer
5. Application of ERTS-1 Imagery to the Sudan Savanna Project, by C. W. Mitchell
6. Automation of Earth Resources Data Analysis, by O. E. Morgan
7. Use of Photographic Imagery for Earth Resources Studies, by Dr. E. S. Owen-Jones
8. Recent results from the use of ERTS, Skylab and other remote sensed imagery in mineral exploration, and their significance in planning future Earth Observation Projects, by N. Press
9. Telespazio Facilities for Acquisition & Processing of ERTS Data, by Ing. B. Ratti
10. The Use of ERTS Imagery, by L. P. White

Offers of further papers are invited. Further details are available from the Executive Secretary.

Space Study Meeting
Theme **SATELLITE TRACKING** by Dr. D. G. King-Hele.
To be held in the Kent Room, Caxton Hall, Caxton Street, London, S.W.1. on **17 April 1975,** 6.30-8.00 p.m.
A general review of the radio and optical methods used in satellite tracking, their effectiveness and some of the results achieved.

Admission tickets are not required. Members may introduce guests.

Space Study Meeting
Title **A DEVELOPMENT STRATEGY FOR A EUROPEAN MINI-SHUTTLE** by D. Ashford.
To be held in the Kent Room, Caxton Hall, Caxton Street, London, S.W.1. on **6 May 1975,** 6.30-8.00 p.m.

Admission tickets are not required. Members may introduce guests.

Main Meeting
Theme **COMPUTERS IN SPACE PROJECTS**
To be held in the Architecture Lecture Theatre, University College, Gower Street, London, W.C.1. on **24 September 1975** *(All day).*

Offers of papers are invited. Further details are available from the Executive Secretary.

Main Meeting
Theme **AERONAUTICAL AND MARITIME SATELLITES**
To be held in the Architecture Lecture Theatre, University College, Gower Street, London, W.C.1. on **25 September 1975** *(All day).*

Offers of papers are invited. Further details are available from the Executive Secretary.

Short Film Evening
A Programme of short (10-15 min.) films not previously screened by the Society will take place in the Botany Lecture Theatre, University College, Gower Street, London, W.C.1. on **29 October 1975,** 6.30-8.30 p.m.

Admission tickets are not required. Members may introduce guests.

Lecture
Title **DIRECT SPACE PROBE INVESTIGATIONS OF COMETS** by Dr. D. W. Hughes.
To be held in the Lecture Theatre, Royal Society of Arts, John Adam Street, Strand, London, W.C.2. on **7 November 1975,** 6.30-8.30 p.m.

Admission tickets are not required. Members may introduce guests.

Repeat Film Show
A Programme of some of the most popular films which have been featured over the past two years, will be held in the Botany Lecture Theatre, University College, Gower Street, London, W.C.1. on **3 December 1975,** 6.30-8.30 p.m.

Admission tickets are not required. Members may introduce guests.

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Assistant Editor:
L. J. Carter, ACIS, FBIS

CONTENTS

COVER

PREPARING FOR THE SPACE SHUTTLE. Members of the Society who visit the Kennedy Space Center in July for the launching of the ASTP Apollo spacecraft will see the runway for the space shuttle under construction. These pictures, just released by NASA, illustrate some of the new constructions and modifications to be made to spacecraft handling facilities between now and 1979. *Top left,* transporter moves flight-ready shuttle, on mobile launch platform, out of the Vehicle Assembly Building *en route* to launch pad. *Right,* how the shuttle orbiter will be received after landing back at Kennedy in the Maintenance and Checkout facility to be built adjacent to the end of the runway; *below,* the orbiter coming in to land on the KSC runway.

National Aeronautics and Space Administration

MILESTONES

December

3 Pioneer 11 makes high-angle pass of Jupiter from south polar region. Closest approach to planet – 26,725 miles (43,000 km) – occurred at 17.22 G.M.T. Gravitational slingshot diverts path towards Saturn which should be reached in 1979. Colour photo's show never-before-seen polar regions of Jupiter; imaging system and UV photometer show well-defined south polar cap on moon Callisto.

3 Orbit of Soyuz 16 is circularised at 225 km altitude inclined at 51.8 deg to equator.

8 Soyuz 16 cosmonauts soft-land some 300 km north of Dzhezkazgan, Kazakhstan, at 11.04 hr. (Moscow time).

10 NASA launches 810 lb. (367 kg) West German Helios spacecraft by Titan IIIE from Kennedy Space Center into solar orbit dipping to within 28 million miles (45 million km) of the Sun after 90 days, well inside the orbit of Mercury.

11 CNES postpones launching from Kourou, French Guiana, of first Diamant BP. 4 rocket which will carry Starlette satellite, until January 1975. Believed that vibration problem affecting launcher's lower stages could damage electronic equipment.

11 *Tass* announces that between 12-30 December Soviet carrier rockets will be launched into two target areas of 40 n. miles radius in the Pacific Ocean centred at 41°10'N, 175°50'E, and 45°40'N, 174°10'E respectively.

12 Soviets launch two SSX-16 solid-propellent ICBM's with single re-entry vehicles over distance of some 6,000 miles (9,656 km) into the Pacific. (Launchings made in the late evening about 4 hr. apart; target areas re-opened to aircraft and shipping the following day.)

18 Franco-German Symphonie 1 experimental communications satellite launched by Delta rocket from Kennedy Space Center at 9.39 p.m. EST into 400-38,500 km transfer orbit. (Orbit was circularized at geostationary altitude 11.5°W above the equator following firing of apogee motor on 21 December).

25 Salyut 3 completes 2,950 revolutions of the Earth at 6 p.m. (Moscow time) during six months of operation – double the preplanned duration. *Novosti* reports that over 400 scientific and technical experiments were made aboard the station which received 8,000 control commands. More than 200 dynamic operations carried out; 70 TV and 2,500 telemetric communications sessions held. Attitude control engines were fired about 500,000 times. Power system generated 5,000 kW of electricity. After a number of closing down operations on command from ground, station's mission was ended.

MAN'S FUTURE IN SPACE

By Captain Robert F. Freitag (USN, Ret).

The procedure he believes man will follow in colonizing the other planets was described by Captain Robert Freitag, Deputy Director of Advanced Programs, NASA Office of Manned Space Flight, in a keynote address at the 32nd World Science-Fiction Convention in Washington last year. Terming the Space Shuttle "the Wright Brothers' Kitty Hawk aeroplane of the Space Age," he said the next move will be to achieve permanent occupancy of space with permanent space stations as a step toward large bases. Using as a topic "Space Travel – the Non-fictional Approach," Captain Freitag's discussion centred around a review of fictional space predictions which have become realities, supporting the adage that fact is stranger than fiction.

Space Stations the Next Step

"In my crystal ball, I glimpse manned orbital facilities – space stations of modular (or building-block) design and ever-increasing size, each building block launched by the Shuttle and its next generation offspring.

"I see both Earth-oriented applications and space-oriented operations, explorations and adventures. For example, there will be a manned Earth resources observatory in orbit. The observer is sitting in what looks like a B-29 bombardier's turret and devotes long duty periods, perhaps four hours at a stretch, to taking any valuable data he sees. The ground keeps him updated on weather and new target possibilities. Such a programme would greatly increase the value and quantity of Earth resources observations data."

Captain Freitag predicted there also will be giant reflectors, which he described as mirrors for microwave energy in geostationary orbit.

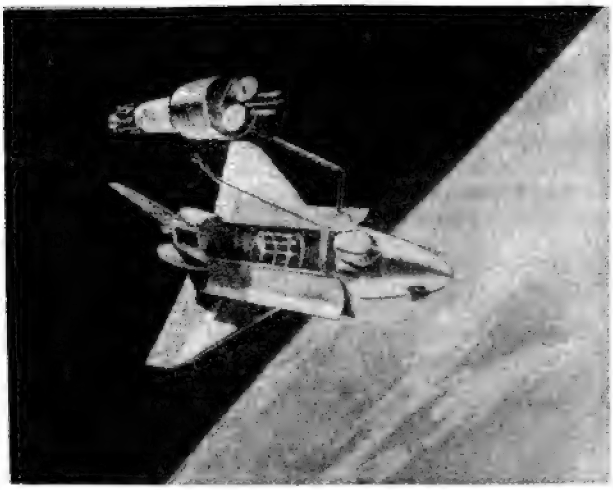
"Large amounts of energy might be transmitted from one point on Earth to another by bouncing microwaves off the orbiting reflector, eliminating the need for Earth-bound transmission means such as cable, fuel tank cars and ships, even pipelines," he added. "There will be solar power collectors in orbit to transform vast amounts of solar energy into electric energy for use on Earth."

"Outlook for Space"

These ideas he identified as some the space agency now is looking at in order to chart a space programme for 1980-2000.

"This study, called 'Outlook for Space,' " he said, "is evaluating potential operational and commercial uses of space.* In particular, we are considering such typical activities as the future of astronomy, astrophysics and other space sciences, manned bases and laboratories in Earth orbit, on the Moon and planets, and space colonization, terrestrial communications and information transfer, monitoring and management of terrestrial weather and environment, space processing and manufacturing, use of space for terrestrial energy supply, interstellar probes, planetary exploration, and the research for intelligent extraterrestrial life.

"Of course, the possible existence of extraterrestrial life, preferably intelligent, and the ramifications of its possible discovery are one of science fiction's most treasured subjects. At a time, a generation ago, when almost all scientists would have pooh-poohed the idea of other life forms in the Universe besides what we know here on Earth, science fiction writers of great imagination were already far into exploring the



Shuttle orbiter in close Earth orbit releases a communications satellite complete with rocket stage for delivery into geostationary orbit.

National Aeronautics and Space Administration

fabulous technological, social, philosophical and humanistic impacts of finding such beings – largely in those science-fiction yarns classed as 'first encounter' stories.

"Today, many scientists – if not the majority – agree that extraterrestrial life surely must exist and possibly in enormous abundance. They even do not shrug off any longer the possible existence of intelligent life in our galaxy. The question now is no longer so much one of 'if' as of 'where'."

He described the search for life in the Universe and the origin of life as one of NASA's most important goals in its science programme and a main thrust behind its planetary exploration projects – past, current and future.

Exciting Space Advances

"You know," he said, "the current year of 1974 has truly been an exciting time for a space buff to be alive! Since the beginning of this year, mankind has visited four planets in the Solar System – Jupiter, Venus, Mars and Mercury. I think the only comparable period of exploration took place in the 100 years or so after the discovery of the New World in 1492.

"NASA's first interplanetary robot Explorer reached Venus 12 years ago (1962), surprising us – and disappointing many – with the finding of a searing surface temperature of 800°F. We reached Mars in 1965, returning the first 20 photos of that planet's surface, which showed that it was cratered. Mariner 4 also brought us the second disappointing surprise that Mars had atmospheric conditions detrimental to most Earth-type life, and neither magnetic field nor radiation belt. Many people started to ask: Was our planet Earth maybe unique in the Universe? What if we are alone? Was truth indeed turning out to be stranger than fiction?

* *B.I.S. recommendations to NASA's "Outlook for Space" study were submitted on 26 September 1974 in three major areas: 1. Interstellar probes; 2. A Lunar Industrial Research Base in Support of In-orbit Manufacture, and 3. Fully Re-usable Launch Systems.*

"We followed Mariner 4 with Mariners 6 and 7 in 1967, and they verified that Mars' atmospheric pressure for the surface was less than one-hundredth that of Earth – and not a tenth, as believed by scientists before that time. Also, there were no canals on Mars.

"But Mars, in spite of the craters, was not a dead planet! We found this out the hard way when our deep-space probe Mariner 9 arrived at Mars right in the midst of the most spectacular dust storm ever recorded. The entire planet was covered with dust! This, too, had never been anticipated in fiction quite like that. After the dust cleared and the sand settled, we discovered three of the largest volcanoes known to man, a gigantic rift valley running around the Martian equator, and countless strange features that looked very much like ancient stream beds.

Mars May Have Life

"There also may be life on Mars, after all – even if its climate is too harsh for other than rudimentary life forms. The fact that we have not found it yet has no meaning for 'absence of evidence is not evidence of absence.'

"All of a sudden, we have a new and exciting Mars on our hands. Our scientists mapped the entire surface of the Red Planet with Mariner 9, made a geological analysis of it, and selected four landing sites for our next major step in the exploration of Mars – Viking.

"NASA is in the final development and testing stages of this ambitious programme which will culminate in the landing of two large robot spacecraft on the dusty, windswept surface of Mars in the summer of 1976 – truly a fitting tribute to the 200th birthday of the United States.

"Prime landing site is at Chryse, at the north-east end of a giant 3,000-mile-long, 20,000-ft. deep rift canyon. Each of these machines weighs nearly four tons and represents a combination biological and chemical laboratory. Each one is entirely self-contained and powered by two nuclear energy generators. They represent mankind's most advanced technology. Their mission: search for life!"

Two questions – "Who is out there?" and "What is out there?" – are providing a major thrust also toward the outer planets of the Solar System, he said, continuing:

"Six months ago, in March, we received our very first pictures from the planet Mercury – 1,700 of them! – when Mariner 10 swept within 400 miles by that small, hot, moon-like world. They showed craters, highlands and maria with a resolution of down to 100 metres. Before that, in February 1974, the robot Explorer had transmitted over 4,000 television pictures from Venus, gliding within 3,600 miles of that mysterious planet which may provide the clues to the mysteries of our own weather system.

The Search Continues

"The search goes on. Late in the Sixties, we realized in NASA that Jupiter, in addition to being a most interesting planet, was the gateway to the outer planets and the galaxy. Thus, on 2 March 1972, one of the all-time greatest adventures in the history of exploration began with the launch of the spacecraft Pioneer 10.

"Travelling 1,000 million kilometres through space, the robot machine reached Jupiter in December 1973, tickling that giant dragon's tail and very much feeling the hot breath of radiation from the dragon – hot enough to bring us right to the brink of what our present technology can take. Overflying its brightly-coloured cloud bands at 81,000 miles altitude, the robot transmitted more than 300 colour pictures across the gulf of 500 million miles. The power of its radio signals when received on Earth was so weak that it would have lighted a 7.5-watt Christmas tree bulb for one-thousandth of a second – after having been collected for 19 million years!

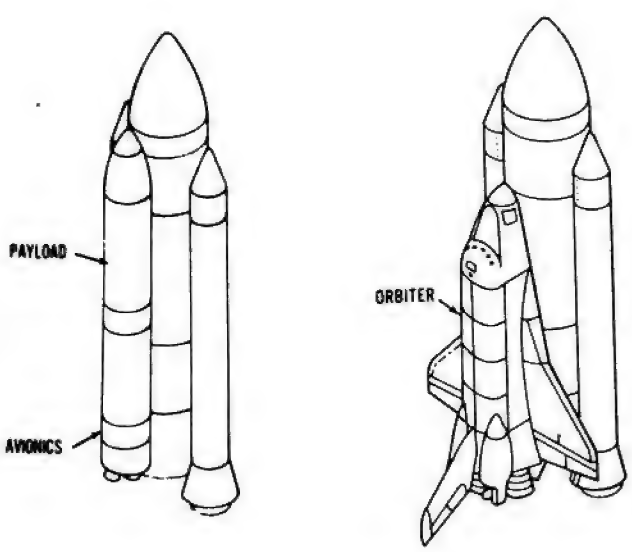
"Imagine! Pioneer 10 has tavelled farther and faster than any other man-made object. It will continue its incredible voyage through the Solar System for the next five years, and it may continue to transmit from as far out as Uranus' orbit, almost 2,000 million miles away. After crossing Pluto's orbit in 1987, it will become the first man-made object to escape the Solar System and to penetrate into interstellar space, headed out on a straight-line course at a permanent 25,000 miles per hour toward the constellation Taurus. In some 1,700,000 years, it should pass the star Aldebaran (or Alpha-Tauri) at a distance of 53 light years. Pioneer 10 may have its first encounter with another civilization. What strange events may then take place, what strange reactions will it cause?

"The spacecraft has been compared to a toy that the infant throws out of his crib as he prepares to grow up and welcome life; it has also been called our collective epitaph and tombstone which will tell the Universe about us long after mankind and the Solar System are gone.

Plaque Carries Message

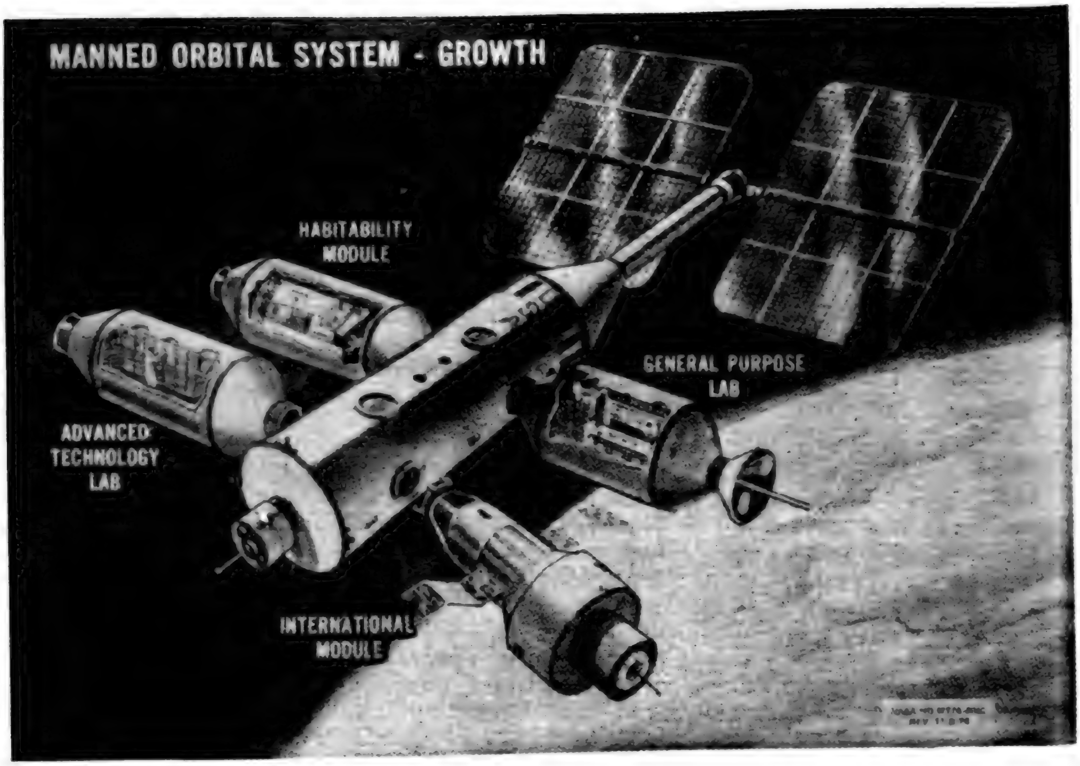
"As you surely know, there is an aluminium plaque aboard the robot messenger on which is written very clearly – not in English or Esperanto, but in scientific – which star of the 250,000 million in our Galaxy sent this greeting card, in which year in the 10,000 million-year history of our Galaxy it was sent, and what type of strange creature sent it. Imagine!

"In December 1974, Jupiter was again visited by another superpathfinder, Pioneer 11, which is now flying on to en-

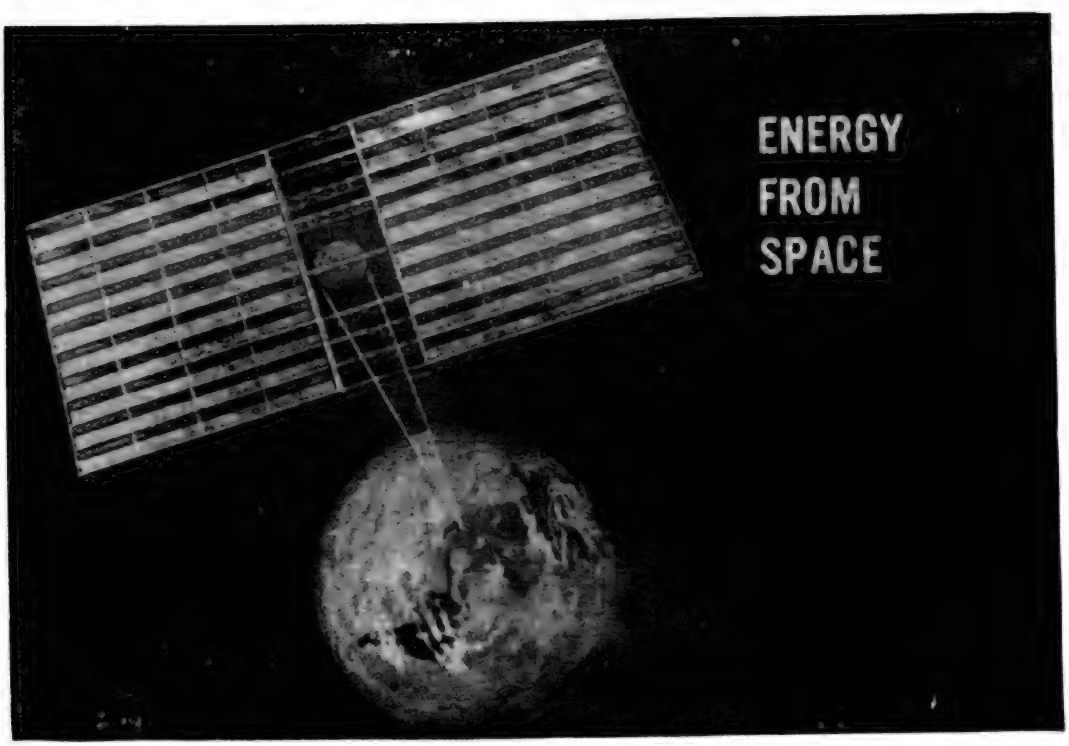


How basic propulsion systems being developed for the Space Shuttle could be applied (left) in the development of a Large Lift Vehicle (LLV).

All diagrams National Aeronautics and Space Administration



Development of a modular space station of expanding capability.



Development of an Operational Energy System in geostationary orbit for beaming power to Earth.

Captain Freitag, 55, is Deputy Director of Advanced Programs in NASA's Office of Manned Space Flight. In this assignment he is responsible for directing work in the area of policy and planning for present and future manned space flight programmes. These responsibilities include the conduct of studies of new manned space systems; development of integrated plans for the future space effort; and the development of policy and management planning for future space activity. The management and direction of advanced development effort for subsystems and components such as propulsion, guidance, structures and other equipment required for future systems is included in this assignment.

Prior assignments with NASA have included Special Assistant to the Associate Administrator for Manned Space Flight from January 1971 to April 1973; Director of Field Center Development for the Office of Manned Space Flight from November 1963 to January 1971; and Director of Launch Vehicles and Propulsion, OMSF from March to November 1973.

Captain Freitag has been involved in the guided missile and rocket field since 1945. These assignments include obtaining rocket and missile information from Germany; aerodynamic development of Navy guided missiles; establishment of supersonic wind tunnels; guided missile intelligence assignments; and direction and establishment of the basic instrumentation system for Air Force Eastern Test Range, Cape Canaveral, Florida.

In 1951, he received a special commendation from the Commander-in-Chief, Pacific Fleet for planning and operations associated with the first Navy guided missiles employed during the Korean War. In 1953-55, Captain Freitag was assigned to the Navy Bureau of Aeronautics, Washington, D.C., where he was in charge of the Regulus missile programmes during which period the Regulus 1 became operational. In 1955 he was Head, Ballistic Missile Branch during which period the basic concepts of the Polaris and Subroc missiles were evolved.

From 1955-57, he was Project Officer in the Office of the Chief of Naval Operations on the Jupiter and Polaris intermediate range ballistic missiles and the Vanguard Earth satellite. During this period, he served additional duty on the Secretariat of Joint Army-Navy Ballistic Missile Committee and on the Staff, Secretary of Defense Special Assistant for Guided Missiles.

Captain Robert F. Freitag (USN Ret.), Deputy Director of Advanced Planning, Office of Manned Space Flight, National Aeronautics and Space Administration.

From 1957-59, Captain Freitag was assigned successively as the Range Planning Officer on the Staff of the Director, Range Support; Pacific Missile Range Planning Officer; and finally as Special Assistant to the Commander, Pacific Missile Range, Point Magu and Point Arguello, California.

From November 1959-63, Captain Freitag directed space and astronautics systems development, supporting research, operational planning, and programme management at the Bureau of Naval Weapons.

In 1957, he was designated "Distinguished Alumnus" by the University of Michigan. In 1959, he was awarded the Legion of Merit for "outstanding services to the Government of the United States from 1949 to 1959, in connection with Naval and National Guided Missile Programs... and for developing and selling the Fleet Ballistic Missile concept to the Navy and the Secretary of Defense..." More recently, he was awarded the Secretary of the Navy Commendation Medal for outstanding performance and achievement as the first Director of Astronautics for the Navy. In 1967, Captain Freitag was awarded the University of Michigan Sesquicennial Award and Medal. In 1969, he received the NASA Exceptional Service Medal for his contributions to manned space flight and the Apollo lunar landing.

Continued from page 83]

counter and explore the planet Saturn in 1979. It also will continue its epic journey into galactic space, and it also carries our greeting card from Earth."

Citing that the enthusiasm for planetary exploratory missions continues to grow in the scientific community, Captain Freitag reported that two more Mariner flights to Jupiter and Saturn are planned for 1977. They will use all-nuclear power like Pioneers 10 and 11 and will carry more than 80 kg of instruments. Their mission will include the reconnaissance of three of Saturn's satellites – Titan, Rhea, and Dione.

He revealed that two Pioneer machines will travel to Venus in 1978, to orbit the shrouded planet and study its carbon-dioxide atmosphere with probes. Orbiters, landers and automated rovers to the planets will follow in the 'Eighties, he reported.

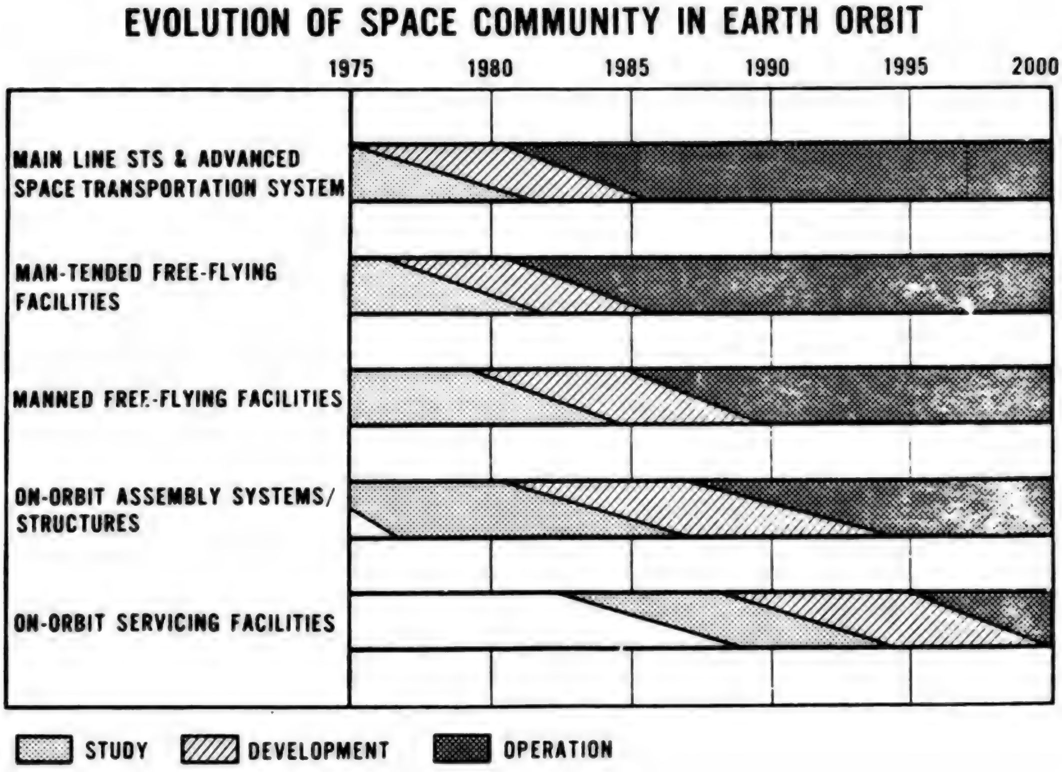
If no life is found on Mars in 1976, he said he believed mankind would still be greatly interested in the planet because it is most likely to support life, as the Earth does.

"Yes," he added, "I think we will then want to begin a really cosmic experiment to see if we can somehow transplant life from the Earth to Mars."

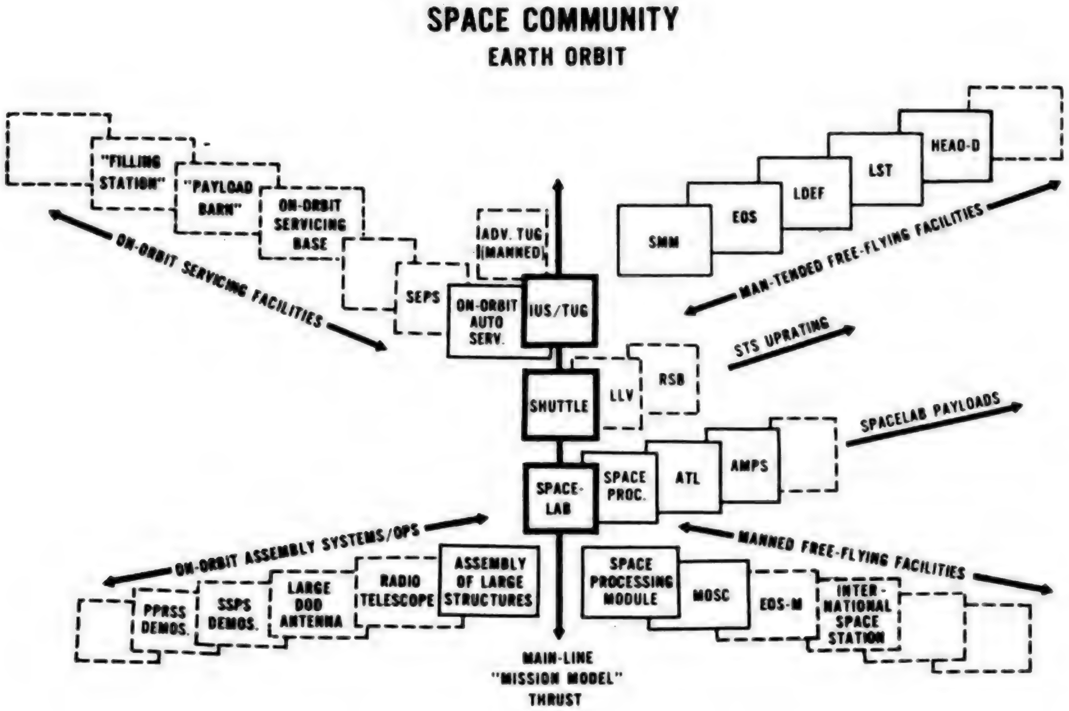
Population Growth Questionable

He turned next to the subject of philosophy:

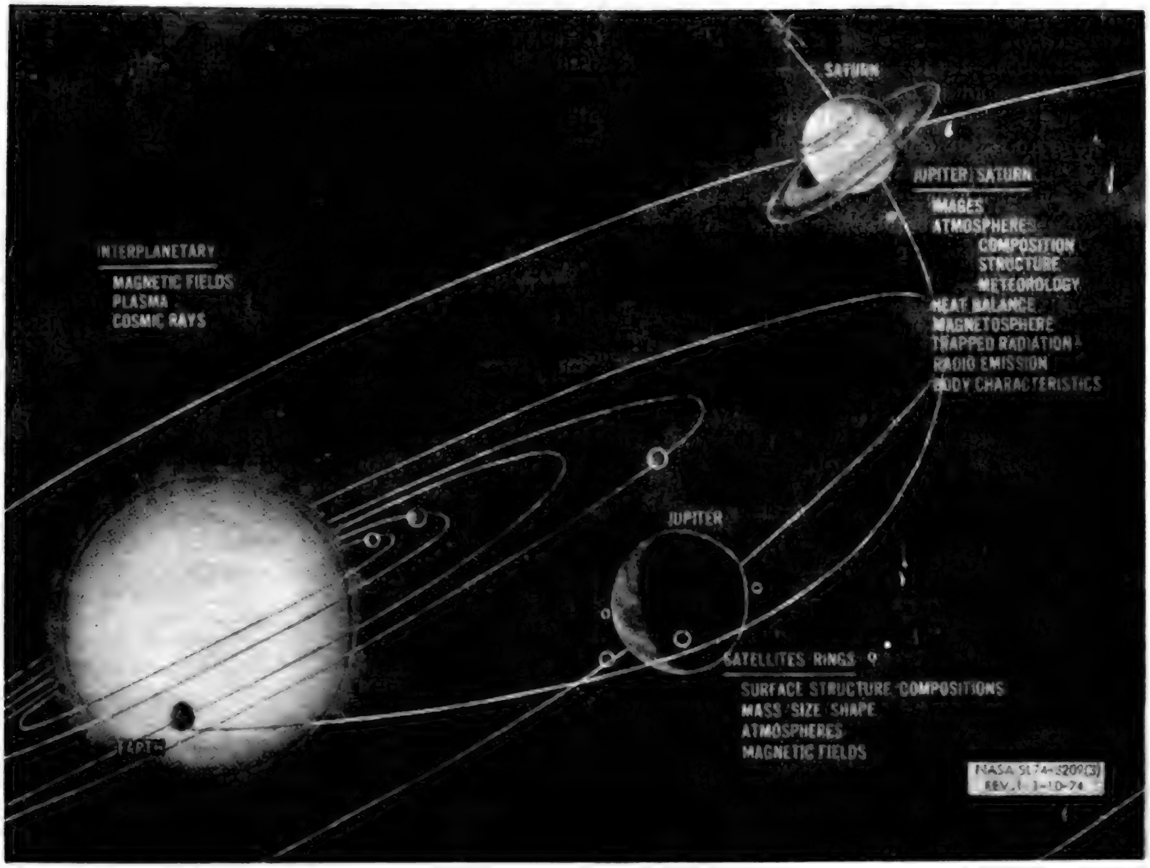
"I see two very striking facts about our world of today – one is the explosive growth of the world's population in the 20th Century, and the other is the advent of space exploration. I feel intensely that these two events do not coincide in time by accident. Some inner motivations are leading



Options for NASA space programmes between 1975 and the end of the century, based on present studies.



Some options for manned space development of the Space Shuttle, Space Lab and Space Tug.



Mariner Jupiter/Saturn 1977 Mission.

mankind to new and unknown shores, and therefore we are gathering our strength and reorganizing our social structures. You see, life is a force which has persisted on Earth for 2,000 to 3,000 million years – which has spread across this planet like a grass fire – which has already gone out to touch the Moon and is even now stretching its sensors out toward the Galaxy. This life will survive for many millions of years more – and to do so it will continue to expand and to weave its way out. Almost instinctively, man will follow this push and settle on other planets.

"Thus, our population explosion may not be a bizarre mistake of nature at all, as some claim; it may be a necessary preparation for space travel as part of our destiny, maybe because the Solar System could probably not be conquered with a mere 3,000 million human beings."

Steps to Reach Other Planets

Captain Freitag gave this procedure for men to follow in colonizing the other planets:

"First, we will probably return to the Moon and establish a base station there, much like the scientific research stations now in existence in Antarctica. The space transportation system presently under development will have the flexibility to support these lunar missions with a minimum of additional developments required.

"The next step will be Mars. Unlike the Moon, Mars will eventually attract permanent settlers intent on colonizing that dynamic world. And our present-day Shuttle might then take its rightful place next to the 'Spirit of St. Louis' in the Smithsonian.

"After the first foothold had been gained, planetary mining and manufacturing experiments will be carried out. Using laser-fusion power, planetary engineers will find ways of mining the planet for resources. They will begin manufacturing the necessary consumables like oxygen, water, food, and fuel. After having reached a certain independence from Earth-based logistics, the colonization project may then move into the phase of environment modification. Large enclosures will be constructed of new space-developed materials, and a more Earth-like environment will be created. By then, the human colony will be firmly established on Mars and the first children will have been born, to become true Martians.

"Flight to the outer planets and their moons will then be as inevitable as the population explosion itself. We know from Pioneer 10 that Jupiter's satellites Ganymede and Io have atmospheres. Maybe they are rich in resources of value to man.

"What surprises await us as greater distances, on the moons of Saturn, for example: We don't know. But we may get an inkling in a few years when we send out new spacecraft."

THE COLONIZATION OF SPACE*

By Dr. R. C. Parkinson

Introduction

Historically, colonization is that activity which follows upon exploration. It implies that use is made of the resources and the new territory discovered for purposes other than those of exploration – for example, for commerical, scientific, social or political ends. With colonization comes the setting up of permanent installations ("bases"), regular transport, and something under the heading of "useful returns". Our endeavours in Space have now reached this point. In the next 20 to 30 years the objectives should be the colonization of near-Earth Space and the Moon.

The commerical exploitation of Space has already begun. TV and telephone conversations routinely bounce off communications satellites, and the firms that build and operate those satellites show a steady profit. The advent of the Space Shuttle, and the materials experiments aboard Skylab, have raised interest in physical manufacturing in the Space environment. The high vacuum and zero gravity environment available in orbit will make large semi-conductor crystals and a range of exotic materials possible. It is but a matter of time before the commercial manufacture of specialist materials in Space is begun, first in the recoverable Spacelab module, but later using permanent Space Stations.

From this start we may expect a chain process to develop. Given that space-borne manufacturing enterprises have been proved successful, then at a certain level it becomes attractive to use Lunar resources to supply these industries [1]. From the beginning of a Lunar Colony we may expect to see a wider use made of the Moon, expanding from an initial exploratory or industrial base. And finally, in the more distant future, with growing activity in the Earth-Moon system, the possibility of using other resources of the Solar System becomes more reasonable.

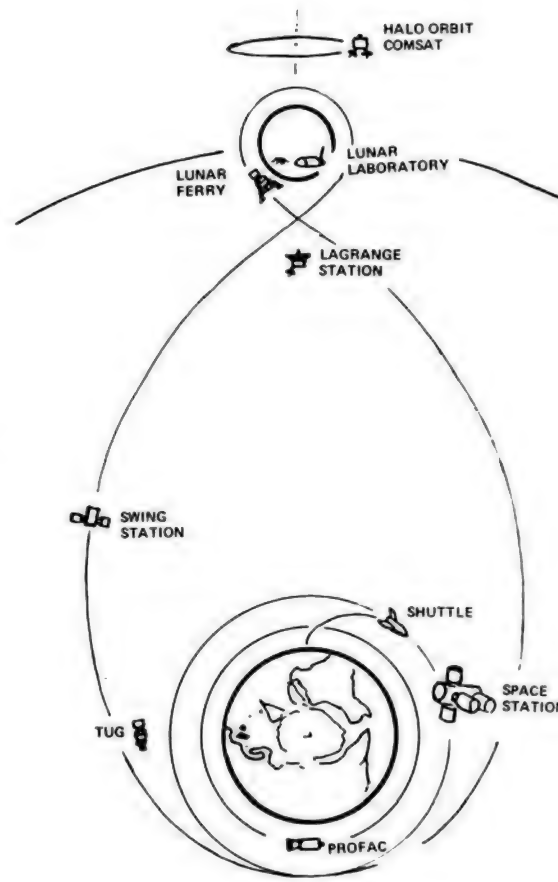
Stations in Space

The early exploitation of space-borne manufacturing processes will almost certainly be based on the Spacelab module, orbited by the Space Shuttle and recovered after each mission. This will represent a learning period, where processes and facilities can be tried out and modified for a relatively modest initial investment. However, once pilot industrial processes have been established, it makes more sense to keep the manufacturing facilities in orbit, and to use the Shuttle only to ferry up raw materials and personnel.

A permanent Space Station would not be the grand affair shown in *2001*, but would most probably be a modular construction [2], allowing for new facilities and growth as new processes were pioneered or demand grew. The Space Station might also be used for other activities – providing a site for scientific research, for the assembly of structures or vehicles too large to be ferried up by a single Shuttle flight, and as a maintenance base for the Space Tug.

As with Spacelab, it is initially proposed to recover the Space Tug after each mission and to bring it back to Earth in the Shuttle Orbiter cargo bay. With a permanent base in a close-Earth orbit and a growing confidence of working in the new environment, the point will come at which it makes more economic sense to carry out the refuelling and refurbishment of the Space Tug in orbit, only returning the vehicle to the Earth after a number of missions.

If space-borne operations are to be exploited early, then provision must be made for a period of learning the new techniques of working in Space. There will be a demand for complex EVA equipment, and for teleoperator "robots"



Outline of transport facilities in the Earth-Moon System, early 21st century.

capable of carrying out difficult tasks under the guidance of a remote operator [3]. But even with such remotely guided "robots" it will make sense to put the operator in Space. From the ground, unless the "robot" is in line of sight, the time lag in communication (mere tenths of a second though it is) will slow the operator's reactions and hinder work.

A Lunar Colony

At the same time that the Space Station is moving from pilot experiments to major industrial activity, extended stay operations on the Moon should be preparing for the next phase. A semi-permanent outpost, with investigations aimed at discovering exploitable resources and extending the range of operations on the Lunar surface would allow for longer term developments.

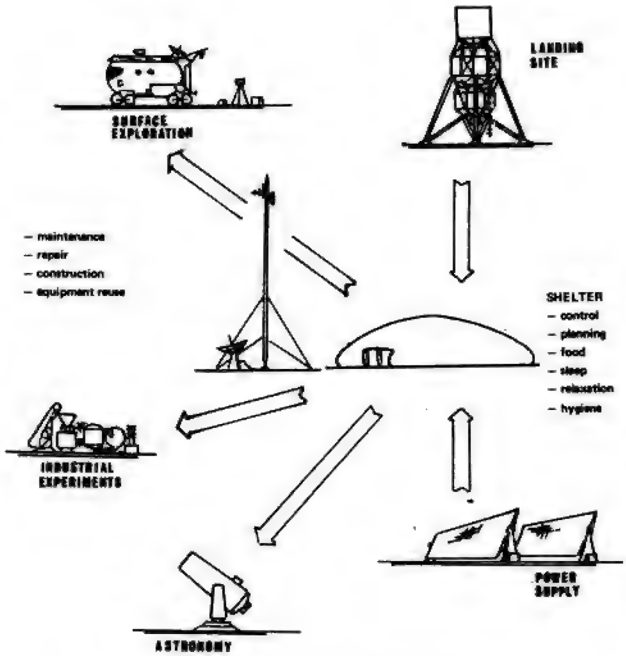
A fairly early objective of a Lunar Base might be to extract oxygen from Lunar surface materials. This would allow operations on the Lunar surface to be extended, and would also show a potential for providing 85% of the pro-

* *One of a series of B.I.S. papers submitted to NASA for the 'Outlook for Space' study (Spaceflight, November 1974, p. 411).*

pellent requirement for liquid oxygen/hydrogen rockets operating off the Lunar surface. It would also provide an early but dramatic example of the value of an Industrial Research Laboratory on the Moon. In the 1980-2000 AD era such a laboratory would be the equivalent of Skylab in the 1960-1980 period.

The Lunar Base will put a greater emphasis on becoming moderately self-supporting than will be the case with orbital stations close to the Earth, owing to the greater transportation costs. Research on closed-cycle environments now may lead to pay-offs in the operating costs of a Lunar Base later.

In the longer term, a Lunar Colony might be expected to provide raw materials for in-orbit manufacturing industries [1], and might also (should the enterprise ever prove possible) provide such things as silicon cells for Orbital Power Stations at costs well below the cost of transportation from the Earth. Shipment of material off the Moon's surface would be by the electromagnetic rail launcher of the sort proposed by A. C. Clarke in 1954 [4]. The economics of such a large installation on the Moon will depend on two things – the cost of transportation of material from the Earth to the Moon, and the demand for Lunar material. It could be economically attractive by the turn of the century.



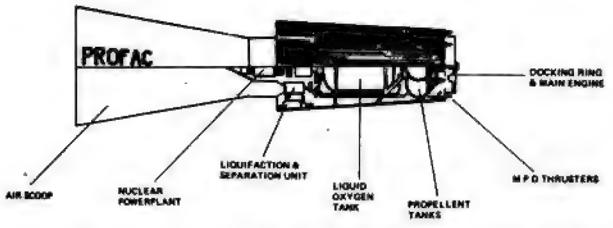
Outline of the operations of an early Lunar Base.

Sky-Mining – PROFAC

Transportation costs are critical in the exploitation of Space. The Space Shuttle represents the first move towards reducing these costs, and cost reductions in this first area will remain important. A re-usable Space Tug would be a natural second stage. But re-usability is a function of performance. If chemical propulsion alone is to be used, then a Tug-boosted *expendable* stage provides the most economic means of placing cargo on the Moon's surface (at a cost of about $4000 kg). Only if a high performance first stage is available (e.g. a nuclear-electric ferry) does it become economic to consider re-using the Lunar landing vehicle.

As already pointed out, 85% of the mass of the propellent of a liquid oxygen/hydrogen engine is liquid oxygen, although the disparate densities of the two propellents means that the hydrogen tank will be much larger than the oxygen tank. If it were possible to provide this liquid oxygen "free in orbit", the cost of transport beyond Earth-orbit could be much reduced.

In 1962, Demetriades [5] proposed that a vehicle in a low-altitude satellite orbit could be used to scoop up the residual atmospheric gases and accumulate a propellent supply for later use. Because the scooped-up air causes a drag on the orbiting vehicle, some of it must be used at once in a nuclear-electric (MHD) thruster to maintain the vehicle's orbit, while the rest is stored. The original scheme was to provide propellent for a later nuclear-electric stage, but it would seem more logical to separate out the oxygen for use in conventional chemical vehicles.



Propulsive Fluid Accumulator Vehicle would orbit at the fringes of the Earth's atmosphere, scooping up residual air and storing liquid oxygen for space propulsion.

The complete PROFAC (for Propulsive Fluid Accumulator) vehicle would consist of a scoop to compress the incoming air, a liquefaction plant and separation unit, a storage tank, and a nuclear-electric thruster system. The air scoop would radiate some of the thermal energy gained in the compression process, and the remaining vehicle surface area would be used as a radiator for the nuclear reactor and the refrigeration plant. With *current* powerplant specific mass and efficiency assumptions, PROFAC could collect its own mass of liquid oxygen, *in orbit*, in about 300 days. Improvements in specific mass and efficiency should be possible, and would make the economics of such a vehicle highly attractive.

As an example, collecting liquid oxygen in orbit for a conventional hydrogen-oxygen rocket would cut transportation costs to the point at which it would be cheaper to use chemical propulsion within the Earth-Moon system than the apparently higher performance nuclear NERVA which must have all its propellent brought up from Earth *via* the Space Shuttle. Using a PROFAC-fuelled Tug transportation system it might be possible to deliver cargo to the Moon at costs below $2000 kg.

Development of the Space Shuttle

The current design of Space Shuttle is intended to deliver cargo into a near-Earth orbit at a cost of between $400 and $500/kg. In any operations in space this cost will be dominant. The present Shuttle represents a compromise between development costs and operating costs. Obviously, as the volume of operations in Space increases, it will become more attractive to consider the development of a second generation

Shuttle in which operating costs are lower. For the moment the first generation Shuttle will provide a degree of economic saving while the techniques required are learned.

There may still be some operations – particularly with large cargoes – when it may be more economical *not* to recover the launch vehicle Orbiter stage. The basic Shuttle configuration might be used, but with an unmanned, non-recoverable stage instead of the Orbiter. Since the valuable part of the Orbiter lies in the engines and astrionics equipment, it may prove possible to package this part as a special "boost unit", to be recovered in orbit and returned to the Earth in due course in the cargo hold of a manned Orbiter vehicle.

It is apparent, however, that the future lies with fully recoverable vehicles, and that real cost reductions may demand the development of single-stage-to-orbit vehicles using air-breathing engines for part of the ascent, as in the Synerjet concept proposed by Escher [6]. There is an analogy here with air travel. We recognize today that large, fan-jet aircraft represent the most economical way of transporting passengers across the Atlantic; but had Boeing, at the time that they were building the Stratocruiser, chosen instead to attempt the 747 they would have found nothing but disaster.

It would seem probable that any descendants of the Space Shuttle will still be chemically powered. There is, however, one other possibility. This is to use a laser-powered vehicle [7], in which ground-based lasers of enormous power (but drawing that power from ground-based power stations) would be used to provide the propulsive energy for a relatively simple ascent vehicle. Fantastic though it may seem (and we are still far from having lasers of such power), if ever such a scheme did prove feasible it could provide the terrestrial equivalent of the Lunar electromagnetic rail launcher, giving high traffic-density, low cost launches for all the payload we might wish to orbit.

The 21st Century in Space

This article has attempted to give a picture of how the commercial aspects of Space might be developed in the period which will take us into the early years of the 21st century. Other reasons for launching payloads into orbit, or for setting up bases on the Moon, have been ignored, even though it seems likely that such operations will continue to account for a respectable number (perhaps even a majority) of Shuttle launches. Space Stations might be used as points from which to assemble large vehicles for interplanetary expeditions, the Moon might provide an attractive base for astronomical research. All of these activities would contribute to the need for an economic transportation system, and would be assisted by the development of permanent facilities for more commercial ends.

An operational view of Earth-Moon space in the year 2000 might contain the following elements. A close-Earth-orbit Space Station with an industrial capacity, serviced by the Space Shuttle and providing a base for Space Tug operations beyond near-Earth orbit. A PROFAC vehicle in a low orbit would collect and supply liquid oxygen for Space Tug operations. Beyond Earth-orbit, a major commercial interest will probably be geostationary orbit, containing communications satellites, meteorological satellites and other applications-oriented activities.

Space Tugs would also be used to inject payloads into a Swing Station orbit [8], shuttling between the Space Station orbit and the vicinity of the Moon, and with regular movement of cargo and personnel between the Earth and the Moon it would be economic to provide a permanent facility in this orbit. A re-usable Lunar Ferry would recover the cargoes and supply the Lunar Base, hopefully using Moon-produced liquid oxygen.

Lunar Base operations would also demand satellite support, at least in the form of a Lagrange-point communications satellite in front of the Moon, and another in a "halo orbit" about the rear Lagrange point to handle communications on the far side of the Moon [9]. The nearer Lagrange point might eventually develop as a pick-up point for handling cargo launched from the Moon by electromagnetic rail launcher.

The programme outlined may seem ambitious, but it is based on the belief that Space can be made to pay. Already it has paid off spectacularly in the field of communications satellites, and it is beginning to pay with Earth resources satellites. Twenty-five years ago the first satellites were being launched. Twenty-five years in the future the Earth-Moon system could be busy with activity.

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CONCRETE ON THE MOON

By Dr. D. J. Sheppard

Introduction

From the viewpoint of the structural engineer the creation of the lunar colony will pass through three phases:

1. Importing complete operational modules from Earth. The current NASA thinking is based on this method of creating a scientific outpost. It will probably be impracticable to manufacture useful materials from the Moon within the confines of these modules.

2. Assembling larger structures from imported components. This phase should produce permanent buildings and small but viable factories.

3. Making structures from lunar resources. This will require a large investment in lunar industry but it will lay the foundations for an expanding and self-sufficient colony on the Moon.

Phase 1 will be based on the sophisticated technology which produced the Apollo landings. In contrast, Phases 2 and 3 require a new technology of lunar manufacture and construction. This technology will borrow a great deal from terrestrial methods, especially civil engineering, and will not necessarily use the aerospace thinking of Phase 1. On Earth the builder has a choice between steel and concrete, each with its advantages and disadvantages. Although aerospace metals seem the obvious choice for lunar structures, there are several varieties of concrete which could have a place in lunar construction.

Lunar Concrete

A typical concrete has three components:

Aggregate – strong fragmented rock which comprises 70-90% of the total mass. Igneous rocks like those on the Moon are ideal.

Reinforcement – ductile metal bars or fibres which give tensile strength to the concrete. Steel bars, other metals and carbon fibres would also be effective in proportions between 1-5% of the volume.

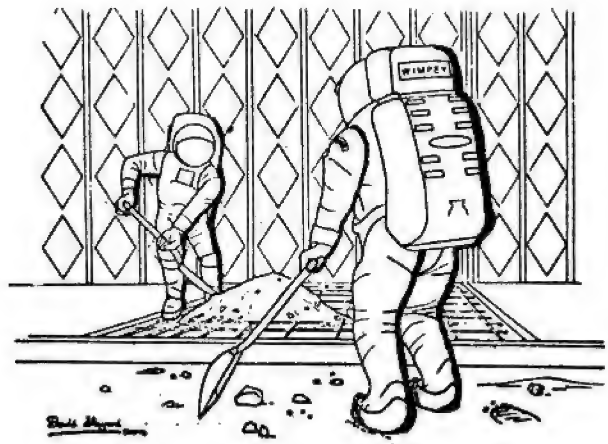
Cement – the glue which sticks the aggregate and reinforcement together. There are at least three possible lunar cements.

(i) *Epoxy resin*

Special terrestrial concretes are made using epoxy resins [1, 2]. These are very strong and inert but more difficult to make than ordinary concrete. For lunar concrete the resin would be imported from Earth, at least until a late stage of lunar industrialisation. Experiment has shown that 9% by mass is the ideal proportion [2]. For easy maintenance the lunar epoxy concrete would be mixed instantaneously in a spray gun. Similar processes are common on Earth, and the only problem is the choice of propellent for vacuum conditions. Sprayed concrete is strong and versatile in application – it can be used on one-sided inflated formwork to give curved shapes.

(ii) *Sulphur*

Melted sulphur can be used as the cement in a fairly strong concrete [3]. Sulphur concrete will be useful on



the Moon if the promised stores of elemental sulphur are discovered near lunar volcanoes. This concrete is made by mixing aggregate and up to 25% of sulphur at a temperature above 119°C, and then pouring the mixture into formwork. This does not take much energy, so it follows that sulphur concrete deteriorates at high temperatures.

This material is not suitable for unprotected outer surfaces; but it should find many applications in floors, foundations, inner walls and protected outer surfaces. The fusibility of sulphur concrete should allow 'welded' joints and repairs; this is an advantage over other concretes.

(iii) *Fused rock*

The rock found on the Moon should melt at 1400-2000°C. On Earth, fused basalt and other rocks are used to make refractories and structural components. A fair amount of energy is needed, but the product is very strong and inert. It should be possible to make a lunar concrete by including compatible reinforcement in the fused rock; titanium is one candidate. Fused rock concrete would probably be unsuitable for site construction, but it could be used for precast structural components, pipes, floor surfaces and refractories. The economics of this concrete would be improved if the molten rock were taken from the metal extraction processes.

Imports of structural mass

Table 1 lists the properties of some potential lunar building materials.

Material	ρ	U.T.S. or *U.C.S. N/mm^2	E KN/mm^2	μ/ρ mm^2/gm	Ideal energy [7] Kw-hr/Kg
Aluminium alloys[5]	2.75	60-650	65-74	2.7	8.29
Iron alloys[5]	7.9	180-1300	210	3.1	1.59
Titanium alloys[5]	4.55	240-1400	105-120	2.9	4.55
Epoxy concrete[2]	2.4	*80-250	30	2.7	0 + reinf.
Sulphur concrete[3]	2.4	*50	30	2.8	0.04 + reinf.
Fused rock concrete[4]	2.8	*150-300	50-100	2.8	0.36 - 1.00 + reinf.

Concrete is usually made by moulding inside formwork which consists of stiffened panels. The reinforcement is either fixed as cages inside the formwork or included as fibres in the concrete mix. Both sulphur concrete and fused rock concrete would use moulds of this type, the mix being heated in special furnaces. The alternative method of making concrete – by spraying the ingredients from a gun – would be appropriate for epoxy concrete and possibly sulphur concrete. This uses formwork on one side only and is best for fancy shapes. After allowing the concrete to harden and gain strength, the formwork is removed and used again.

The value μ/ρ is the mass attenuation coefficient [6] for 6 Mev γ rays; this should provide a basis of comparison for the radiation shielding properties of the different materials.

The mass of material having to be imported from Earth will be a very important factor in the cost of lunar construction. This table confirms the obvious fact that concrete is too inefficient a material to be worth taking to the Moon. This has very little bearing, however, on whether concrete is an efficient material to make on the Moon. The attraction of concrete is that its major constituent – aggregate – is already lying around on the Moon waiting to be used. Even when metals are extracted from the lunar rock, they will not necessarily have any advantage because they will still require imports of the rare alloying elements which transform relatively weak parent metals such as iron into strong structural materials. When lunar metals are available in Phase 3, the reinforcement will also be available on the Moon. This would make lunar sulphur concrete and fused rock concrete almost entirely independent of Earth imports, except for the small amount of alloying elements in the reinforcement. Table 2 compares the percentage of imports for the various metals and concretes.

Table 2

Phase	Material	Imported constituents	Mass imported
1	Aerospace metals	All	100%
2	Aerospace metals	All	100%
2	Epoxy concrete	Epoxy resin, reinforcement	10-15%
3	Lunar Al alloys	Rare alloying elements*	0-9%
3	Lunar Ti alloys	Rare alloying elements*	0-17%
3	Lunar Fe alloys	Rare alloying elements*	0-3%
3	Epoxy concrete	Epoxy resin	9%
3	Sulphur concrete	a) Reinforcement b) R.A.E.* for reinf.	1-6% 0-1%
3	Fused rock concrete	a) Reinforcement b) R.A.E.* for reinf.	1-6% 0-1%

* *Cr, Cu, Mn, Mo, Nb, Ni, Sn, V, W, Zn, Zr.*

These percentages have been derived assuming that Phase 3 lunar industry will extract Aluminium, Carbon, Iron, Magnesium, Silicon, Sulphur and Titanium from native resources. The relationship between strength, specific gravity and mass import percentage is best expressed as a Specific Import Mass for each material. Table 3 lists the values for strength, stiffness and shielding; these can be interpreted as the total imported masses required to resist a standard load, deflection and radiation flux. The units are arbitrary for each category.

Table 3

Phase	Material	Specific import mass			Energy
		Strength	Stiffness	Shielding	Specific strength
1, 2	Aerospace metals	4000-7000	390	320-370	0
2	Epoxy concrete ≤ 6% imported reinf.	1000-4500	80-120	37-56	0
3	Lunar Al alloys	0-400	0-35	0-33	350-4200
3	Lunar Ti alloys	0-710	0-73	0-59	150-870
3	Lunar Fe alloys	0-400	0-11	0-9	90-670
3	Epoxy concrete				
	≤ 4% lunar Al reinf.	870-3250	72-75	32-35	3-100
	≤ 6% lunar Ti reinf.	870-2810	72-81	32-37	3-82
	≤10% lunar Fe reinf.	870-2800	72-74	32-35	2-48
3	Sulphur concrete ≤ 6% imported reinf.	480-2900	8-48	3-22	19
3	Sulphur concrete				
	≤ 4% lunar Al reinf.	0-170	0-3	0-1	35-178
	≤ 6% lunar Ti reinf.	0-490	0-8	0-4	32-149
	≤10% lunar Fe reinf.	0-150	0-2	0-1	27-94
3	Fused rock concrete ≤ 6% imported reinf.	90-120	3-34	3-22	31-185
3	Fused rock concrete ≤ 6% lunar Ti reinf.	0-190	0-6	0-4	36-226

For Phase 2 structures it will be seen that epoxy concrete has a big advantage over the aerospace metals, especially in those applications where stiffness or shielding are important. Epoxy concrete loses this superiority in Phase 3, but then the sulphur and fused rock concretes take over as the most efficient materials. Even if the reinforcement is imported from Earth, the fused rock concrete is more efficient for providing stiffness or shielding. If lunar metal reinforcement is used, then both the sulphur concrete and the fused rock concrete are far superior to the metals in all categories. A low alloy steel is the most economical reinforcement for sulphur concrete, while titanium must be used with the fused rock.

Energy

Power will be an expensive resource on the Moon, so it will be important to minimise the energy requirement for the lunar construction industry. Table 3 compares the extrac-

tion energy needed for different materials to make a structure which can support a standard load. The figures do not include the energy required for mining, forming or construction. It will be seen that all the lunar concretes require significantly less energy than the metals.

Labour

On Earth a concrete building uses more labour than a steel building. The labour content of concrete is high because all the operations are performed on site, whereas much of the labour in steel is hidden in the steelworks and the fabrication shop. Most of the labour in concrete is needed for cutting, shaping and fixing the cages of reinforcement. If the reinforcement is imported from Earth, these operations can be delegated to terrestrial labour. Most of the remaining labour content in concrete is required for constructing the formwork. This element can be reduced considerably by using prefabricated formwork which is designed for easy erection. Adding both these savings together, it should be possible to reduce the labour content of Phase 2 concrete to the level of metal erection. During Phase 3 the balance favours concrete because the extraction, forming and fabrication of metals will require much more labour than the melting of sulphur or rock. It so happens that reinforcing bars are the simplest type of metal section to make.

Equipment

The Phase 2 operations will resemble construction at remote sites on Earth. Without detailed feasibility studies it is not possible to compare the equipment needed for concrete and metals. Experience with terrestrial construction would suggest, however, that concrete will require a greater initial mass but less resupply because the equipment will need less maintenance.

For Phase 3 both concrete and metals will require mining, transport and separation equipment, as well as furnaces. In addition, the lunar metals will have to be extracted chemically, treated, formed and fabricated. It seems certain that the metals in Phase 3 will use more equipment than the concretes.

Reliability and Flexibility

The Apollo landings showed that even the most carefully designed equipment is liable to fail in the rough and tumble of lunar surface operations. The more sophisticated the equipment is, the more likely it is to break down, and the harder it is to repair. This is a critical problem on any construction site, even more so on the Moon where the supply line is very tenuous and any maintenance facilities are at a premium. Clearly the lunar machinery must be as reliable as possible. Increased reliability will compensate for added initial mass. It is also important that no item of equipment is critical to the construction process, so that the disabling of that one item would stop the entire process. Concrete scores heavily over metals on the grounds of reliability and flexibility; the following list gives some of the reasons why.

(i) Concrete equipment is simpler and therefore less likely to fail and easier to maintain if it does.

(ii) Concrete can be produced by one man with a shovel if the machinery breaks down; this gives flexibility in emergency.

(iii) Concrete requires little industrial infrastructure, which is why it is one of the first products of any emerging nation.

(iv) It uses metals in their most easily manufactured form – bars.

(v) Concrete uses a large proportion of unskilled labour. Anyone can lend a hand if necessary; this gives flexibility for manpower planning.

(vi) The transition from Phase 2 to Phase 3 is gradual and does not require a large and possibly prohibitive investment in extraction plant and industry. This will reduce the budgeting problem.

(vii) Concrete becomes increasingly competitive from Phase 2 onwards. A decision to turn to concrete might be found to be premature, but it will not be wrong in the long term.

Other Advantages

Concrete has the following properties which are not shared by metals and which are desirable for the lunar colony.

(i) Low thermal conductivity.

(ii) Damping of noise and vibration.

(iii) Its failure is gradual and foreshadowed by warning cracks.

(v) Easily repaired.

(vi) Familiar, Earthlike appearance.

(vii) High self-weight. This is important for pressurised buildings, where the negative air pressure is dominant.

Applications

Metals are strong in tension but weak in compression because of buckling. Concretes are strong in compression but weak in tension because of brittle fracture. This difference will decide the applications of concrete on the Moon, and the shape of lunar concrete structures. Tensile membranes such as domes and cylinders are unsuitable, although prestressed concrete construction might eventually be used for this purpose. The most efficient shape for reinforced concrete is concave compressive arches, perhaps in the form of lobate walls and roofs. The latter would hold a layer of lunar soil to balance internal air pressure and provide extra radiation protection. These shapes would be difficult to make, however, and a less efficient but much simpler solution would be to make Earthlike buildings with four perpendicular walls and a flat roof. A wall around the roof would retain the soil overburden.

It will be possible to build most lunar structures from concrete. The exceptions are vehicles, lightweighted antennae and inflated structures. Concrete should be most useful for foundations, tunnels, roads, tracks and launching pads. The superior specific stiffness of concrete makes it the best material to use for the proposed lunar accelerator [7]. The construction of inhabited concrete buildings will obviously require some careful experimentation, but the material seems ideal for this application.

Concluded on page **114.**

INDIA IN SPACE

By Theo Pirard

This year India takes a major step into the Space Age by having her own scientific satellite launched from a Soviet cosmodrome. At the same time preparations are being made to move NASA's ATS-6 satellite from its present geostationary position above the Galapagos Islands in the Pacific to a new location above Kenya within sight of the Indian subcontinent, there to begin one of the most important social experiments of out time – the direct re-transmission of educational television to thousands of remote communities. This article traces the new awareness for Space which is growing in India and which may lead the nation to launch satellites for a wide range of purposes including communications, educational broadcasting, advance warning of storms and the monsoon (critical to the planting and harvesting of crops), and Earth resource observations.

Introduction

India has a very active programme of space technology, as well as an important nuclear research programme. Both activities had their basis in the ideas of Dr. Vikram A. Sarabhai (1919-1971) and are being pursued with some success. The first Indian atomic bomb – "a peaceful nuclear explosive" – was tested under-ground in May 1974. According to the long-term activities of the Indian Department of Space, a national satellite-launching capability will be acquired during 1978.

The Indian Space Research Organisation (ISRO), which has the main management responsibility for space activities, recently obtained a licence to manufacture the Viking turbopump rocket engine. This engine, developed by the Société Européenne de Propulsion (SEP), is being used in the first and second stages of the European 'Ariane' heavy satellite launch vehicle. In this way, India intends to realise by its own efforts a large rocket which eventually will place payloads of about 1 ton into a geostationary orbit. In particular India wishes to have a launch vehicle both for her own purposes and which can be placed at the disposal of the developing of nations for orbiting communications, meteorological and Earth resources satellites...

With technical assistance from foreign countries, especially France, the United States and the Soviet Union, Indian scientists and engineers have been getting acquainted with the rocketry and electronics needed for such a major space venture.

An International Base

The background to these activities is broadly as follows. In August 1961, the Government placed space research activities in India under the sponsorship of the Department of Atomic Energy (DAE). The Indian National Committee for Space Research (INCOSPAR), formed in 1962 under the Chairmanship of Dr. Vikram A. Sarabhai, directed all space activities until 1969. After 15 August 1969, separate bodies, INCOSPAR and the Indian Space Research Organisation (ISRO), became responsible for space research in India.

In June 1972, the Indian Government created a separate Department of Space and a Space Commission. Now ISRO is functioning under this Department and its activities are carried out mainly at two major centers, in Trivandrum and Ahmedabad, with headquarters in Bangalore.

After the death of Dr. Vikram A. Sarabhai on 30 December 1971, the facilities established at Trivandrum, near Thumba, have received the name of the Indian space research promoter, i.e. the Vikram Sarabhai Space Centre (VSSC). This Centre is composed of the following units:

Space Centres in India:

I *ISRO Headquarters,* Bangalore.

II *ISRO Office,* Bombay.

III *ISRO Office,* Delhi.

IV *Vikram Sarabhai Space Centre (VSSC),* Trivandrum.

1. Thumba Equatorial Rocket Launching Station (TERLS) 2. Space Science & Technology Centre (SSTC) 3. Rocket Propellent Plant (RPP) 4. Rocket Fabrication Facility (RFF) 5. Propellent Fuel Complex (PFC) 6. Indian Scientific Satellite Project (ISSP), Bangalore.

V *Space Applications Centre (SAC),* Ahmedabad.

1. Experimental Satellite Communications Earth Station (ESCES) 2. Satellite Communications Systems Division (SCSD) 3. Remote Sensing & Meteorological Applications Division (RSMD) 4. Electronics Systems Division (ESD) 5. Microwave Division (MID) 6. Audio Visual Instructional Division (AVID) 7. Satellite Instructional Television Experiment (SITE).

VI *Sriharikota Range (SHAR),* Sriharikota.

1. Sriharikota Launch Complex (SLC) 2. Rocket Sled Facility (SLED) 3. Static Test and Evaluation Complex (STEX) 4. Solid Propellent Space Booster Plant (SPROB) 5. Sriharikota Common Facilities (SCF).

Thumba Equatorial Rocket Launching Station (TERLS);

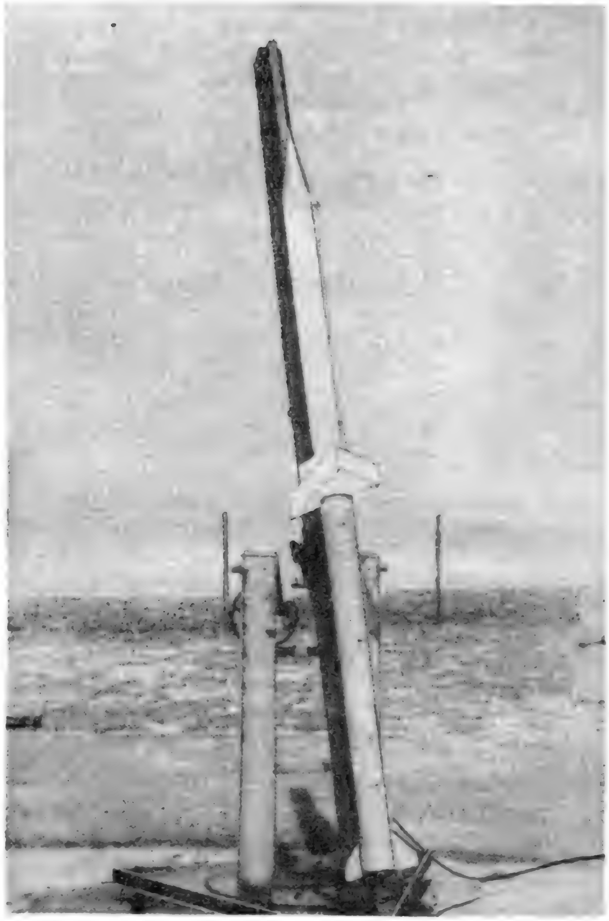
Space Science and Technology Centre (SSTC);

Rocket Propellent Plant (RPP);

Rocket Fabrication Facility (RFF).

Theo Pirard is Space Editor of the Belgian monthly publication 'Aviation and Astronautique'.

Rohini RH-125 on launcher.



Rohini RH-MSR-1 on launcher.

It manages also the Shriharikota Range (SHAR) and all the works concerning this future satellite launching station.

TERLS is a United Nations' sponsored sounding rocket range established in late 1963 for experiments in the region of the Earth's magnetic equator which runs close to Thumba. The normal launch area (latitude 8°32'N, longitude 76°51'E) covers about 560 acres and launchings are carried out over the sea to the west of the area.

This Station provides facilities for launching many types of sounding rockets, including the French Centaure and Dragon, the Indian Rohini 75, 100 and 125, Centaure and Menaka, the British Skua I, Skua II and Petrel, the American Nike Apache, Nike Tomahawk, Arcas and Judi, and the Soviet M-100 meteorological rockets. Since 21 November 1963 when TERLS became operational after the successful launch of a NASA Nike-Apache, more than 640 rockets have been launched from these facilities.

SSTC was set up in 1966, near TERLS, for developing indigenous sounding rockets and acquiring experience in space engineering, and for preparing and testing scientific payloads and, ultimately, satellites. It is the Research and Development Unit of the VSSC.

RPP and RFF were established respectively in 1969 and in 1971, in order to supply propellents primarily for the Indian-made Centaure and to manufacture hardware and rocket motors for the Indian rockets Menaka I, Menaka II, Rohini 100, Rohini 125, Rohini 300, Rohini 560 and their multiple combinations. The most important task of ISRO, at VSSC, is to develop indigenously a satellite launch capability. SSTC intends to progress towards the projected Rohini SLV-3 satellite launcher *via* the Rohini family of sounding rockets of steadily-increased technological complexity.

A scientific payload of instruments completely fabricated in India was launched successfully at TERLS for the first time by a two-stage French Centaure on 29 April 1965. Subsequently, the Indian space authorities acquired a licence agreement for the manufacture of Centaure. Meanwhile, in order to become better acquainted with the technology of solid-propellent rockets, in 1969 Indian engineers began development of the small RH-75 sounding rocket. This served both as a training aid for open site radar operators and as a vehicle for testing the properties of propellents under dynamic conditions.

Other indigenous rocket projects were to follow:

RH-100: used for improving the aerodynamic design of rockets and the checkout of electronic systems in flight, also provides a booster for the Menaka I meteorological payload

and other applications.

RH Multiple Stage Rocket: provides experience for multistage rockets which involve staging techniques, destruct system, clustered grain boosters and separation devices; it provides a booster for the Menaka II.

RH-300: a single-stage rocket, using indigenously developed propellents, serves for meteorological studies and for "D" region observations in the upper atmosphere.

RH-560: a powerful 2-stage solid propellent rocket used for high-altitude sounding experiments; flight tests began in January 1973. A first successful launch occurred on 23 April 1974.

RH-SLV-3: ultimate in the Rohini rockets family; it will be a light-weight satellite launch vehicle, with its four stages powered by solid propellents, with inertial guidance.

Special materials and methods of construction involved in advanced aerospace engineering are being developed for use in the rocket motors; propellents of high performance are in production and chambers of 560 mm diameter are under test. The first attempt to place a small satellite into orbit – the RS-1 (Research Satellite n°1) – should occur in 1978.

The SLV-3 will be followed in the early 1980's by more important satellite launch vehicles using more powerful motors, and, for some stages, hybrid propellents. Initially, the aim is to launch a 100 kg spacecraft. But the final objective of SSTC is to realise a launch vehicle capable of putting an 800 kg satellite into synchronous orbit at about 40,000 km. From the very modest Rohini 75 to the heavy launch vehicle is a large step. VSSC is already studying the liquid propulsion systems.

New Launch Site

The Indian programme for development and use of larger and more powerful rockets made it necessary to establish a launch site far from populated areas, on the East Coast of India. SHAR is situated on the Sriharilota Island (latitude 13°47'N, longitude 80°15'E), about 62 miles (100 km) by road from the city of Madras, and is suitable for development into a satellite launch centre. Based on the technology developed at VSSC, a Solid Propellent Space Booster Plant (SPROB) is being set up alongside other facilities of SHAR; when completed in mid-1976 this plant will produce monolithic grains of solid propellents weighing up to 10 tonnes each. A Static Test and Evaluation Complex (STEX) to test the next series of large boosters and rocket motors is also being built; motors will be tested conventionally on stands, as well as in space simulation chambers. A tracking radar for use at the Sriharikota Launch Complex has been designed at VSSC.

The RH-300 and RH-560 motors have been flight tested and are regularly fired, while a launch complex including a tower for launching the future SLV-3 is now under construction.

A Centre for Applications Satellites

ISRO established a technical centre at Ahmedabad especially for the study of applications satellites and their systems. This is the Space Applications Centre (SAC) which has the following facilities:

Experimental Satellite Communication Earth Station (ESCES);

Satellite Communications Systems Division (SCSD);

Remote Sensing and Meteorological Applications Division (RSMAD);

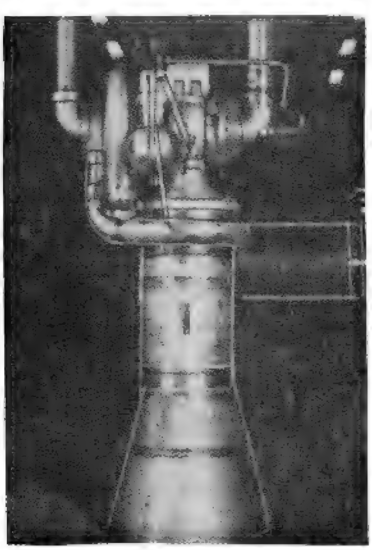
Electronics Systems Division (ESD);

Microwave Division (MID); and

Audio Visual Instructional Division (AVID).

Of particular importance is the ISRO project of Satellite Instructional Television Experiment (SITE) which India decided to conduct in collaboration with NASA in September 1969. This involves the broadcasting of Indian instructional TV programmes to about 5,000 villages in different parts of the country. The NASA-Fairchild ATS 6 spacecraft*, launched on 30 May 1974, will be made available to India during

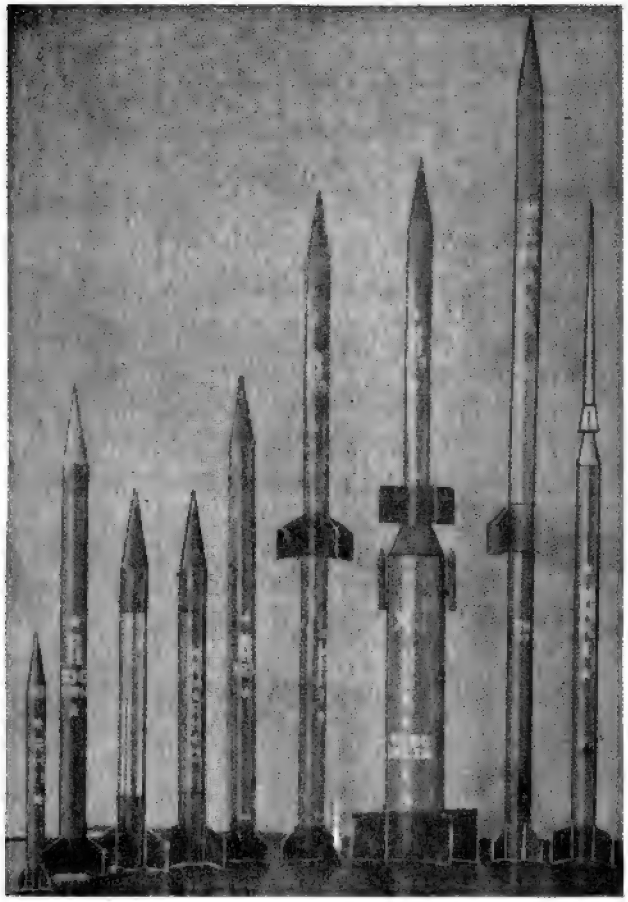
* *"The Community Satellite", 'Spaceflight', September, October, and November 1974.*



Left, engineering model of the French SEP Viking rocket engine for which the Indian Space Research Organisation (ISRO) has acquired manufacturing rights.

Right, another important application of space technology in India concerns communications satellites and the direct broadcasting of educational TV. Photograph shows the Experimental Satellite Communications Earth Station at Ahmedabad.

Indian Space Research Organisation (ISRO)



Left, Rohini RH-560 flight tested in 1973. *Right,* Family of research rockets built in India: *left to right,* RH-75, RH-100, RH-125, RH-125, RH-MSR-1 (RH-125 + RH-125), RH-MSR-2 (RH-300 + RH-125), Menaka 2 and Menaka 1.

All photographs Theo Pirard except where otherwise stated

Model of four-stage Rohini SLV-3 which India is developing for launching small satellite payloads.

India's Rocket Programme.

Name	Stages	Length overall (cm)	Max. body diameter (cm)	Weight at launch (kg)	Payload (kg)	Launch angle (°)	Peak altitude (km)
Rohini 75TR	1	1,019	7.5	6.85	1	65	5
Rohini 75	1	1,512	7.5	10	1	65	9
Rohini 100	1	2,027	10	24.55	3.2	65	14
Menaka I (Rohini 100 + Dart)	2	2,889	10	25.88	4.15	82	58
Rohini 125	1	1,660	12.2	27.88	4	65	11
Rohini 125 + Rohini 75	2	3,172	12.2	37.3	1.1	85	93
Rohini 125 + Rohini 100	2	3,687	12.2	51	3.2	85	100
Menaka II (Rohini 125 + Rohini 125)	2	3,789	12.2	58.8	3.5	85	100
Indian Centaure	2	5,900	30.5	530	57.3	82	136
Rohini 300	1	4,850	31.6	420	40	85	100
Rohini 560	2	7,643	56	1,391	100	80	334
Rohini SLV-3	4	19,440	100	17,337	30 (in orbit)	80	400 (in orbit)

1975 for this purpose. About 2,000 sets, designed and developed by ESD, will be of the direct reception type capable of receiving signals directly from the satellite; sets can be located almost anywhere, even in villages without electricity.

ESCES, which be the prime station during the experiment, will be used for transmitting TV programme material to the satellite and for monitoring these transmissions. AVID will look after the instructional objectives of the project. After this experimental demonstration, ISRO expects to employ national communications satellites for educational programmes.

Already ISRO has made various satellite system studies to define an overall system for an Indian National Satellite (INSAT) for television and telecommunications. The concept of a multiple beam satellite was proposed by ISRO in August 1972. The following programme was recommended:

1976: INSAT-I-1 procured and launched abroad.

1978: INSAT-I-2, back-up satellite, also procured and launched abroad.

1981: INSAT-II-1 of Indian fabrication and launched from SHAR by an indigenous launch vehicle.

1986: INSAT-II-2 also made in India and launched by ISRO.

In all these activities, the ISRO headquarters at Bangalore have not forgotten the scientific aspects of space research. To prepare the Indian capability for developing its next satellites, scientists and engineers of SSTC, Trivandrum, are using special facilities at Bangalore for the indigenous design and fabrication of India's first scientific satellite. Under a collaborative programme between India and the USSR, this spacecraft is to be launched in April from a Soviet cosmodrome using a Cosmos launch vehicle.**

The Indian Scientific Satellite which is spin-stabilized is quasispherical in shape and weighs about 250 kg; it should enter an elliptical orbit with a perigee of 265 km and an apogee of 600 km. It has three experiments concerned with X-ray astronomy, solar-neutron and gamma-rays and the measurement of ionospheric parameters. The necessary ground telemetry and telecommand stations are now established at Sriharikota.

To Shape India's Future

How can one explain this major space effort in India? The best answer was given by the founder of ISRO, Dr. Vikram Sarabhai: "I believe that several uses of outer space can be of immense benefit to developing nations wishing to advance economically and socially. Indeed without them, it is difficult to see how they can hold their own in a shrinking world... We do not have the fantasy of competing with the economically advanced nations in the explorations of the Moon or the planets or manned space flight. But we are convinced that if we are to play a meaningful role nationally, and in the community of nations, we must be second to none in the application of advanced technologies to the problems of man and society, which we find in our country."

Acknowledgements

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** *"India's Space Plans", Spaceflight August 1974, p. 312.*

X-RAY ASTRONOMY IN INDIA

By H. P. Mama

Introduction

Even after our Sun had been identified as a source of X-rays, few astronomers had expected to receive these radiations from distant stars. The Sun's steady X-ray emission is negligible compared to its output in visible and radio radiations. On that basis, even radiations from the nearest star would fall well below the threshold of detection at the distance of the Earth. There was great excitement in 1962 when the first X-ray source Sco X-1 was discovered in the constellation Scorpio by R. Giacconi and H. Gursky of American Science and Engineering, Inc., and Bruno Rossi of the Massachusetts Institute of Technology. Though perhaps hundreds of light years away, its X-ray flux was far greater than that of our Sun, just 150 million km from Earth. Thus Sco X-1 should be about a billion times more powerful a source of X-rays than the Sun. This chance discovery led to the science of X-ray astronomy. Since then, about 40 sources had been observed with rockets and a few with balloons. The picture changed dramatically with the launching of the first United States X-ray astronomy satellite, Uhuru (Swahili for independence) from the San Marco platform off the coast of Kenya on 12 December 1970.

While X-rays can penetrate sheets of lead several millimetres thick, the Earth's atmosphere has the shielding properties of lead a metre thick. Thus these radiations can be detected primarily by instruments lifted beyond the Earth's sensible atmosphere. Only the hardest X-rays ever penetrate down to balloon altitude of about 35 km.

Balloon Experiments

The Tata Institute of Fundamental Research launched its first balloon-borne X-ray payload on 28 April 1968, and a total of eight successful flights have been made to date. The Institute's facility at Hyderabad fabricates plastic balloons of up to 115,000 metres^3 capacity, capable of carrying 100 kg payloads to altitudes up to 37 km.

Pioneering balloon-borne experiments at the TIFR is Professor G. S. Gokhale who heads the Balloon High Altitude Studies Group which manufactures the balloons, fabricates the instrumentation and payloads, and launches them from

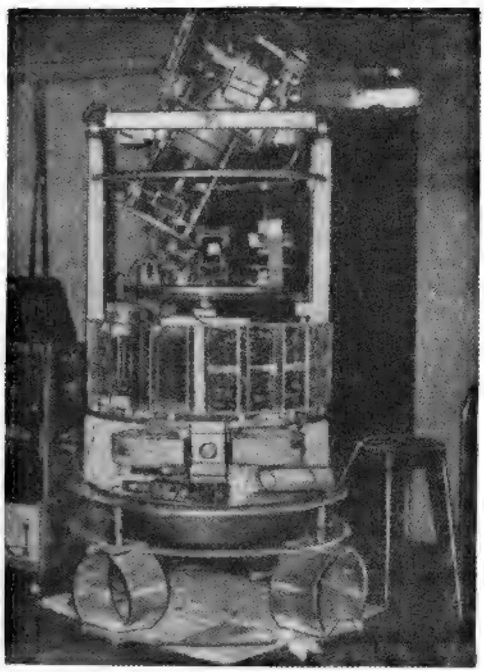
Hyderabad. Professor Gokhale has been associated with cosmic ray research with balloons for almost a quarter of a century and is in charge of this work at Hyderabad.

Balloons for night flights are made of a specially toughened Stratofilm polyethylene fabric produced by the United States,Winzen Company – the only manufacturer of such fabric in the world. These balloons are about 70 m long at launch and cost about Rs.30,000 each, while the payload may cost another Rs.15,000. In spite of that, the balloon is still the most economical vehicle for these studies.

Hyderabad is ideally situated for experiments in X-ray astronomy. Since it is close to the geomagnetic equator, the Earth's magnetic field is very intense and the cosmic ray background is thus much lower than at higher latitudes. The low background radiation permits the study of weaker sources and makes possible the extension of the energy spectra to high energies where the flux is low. Known X-ray sources in both the northern and southern hemisphere can also be observed from Hyderabad. This ideal location has attracted many foreign scientists to work at Hyderabad, particularly those from Japan.

For the prolonged observation of an X-ray source, the balloon payload is stabilised around the azimuth. Its position about the vertical axis is continuously monitored by a magnetometer which uses the Earth's magnetic field for reference. Any drift from the desired direction is corrected by signals to a servo system. The X-ray telescope is thus focused on the target to an accuracy of about a degree of arc.

Apart from the X-ray telescope, the balloon carries equipment to continuously give information on the azimuth and altitude. Information on the altitude is essential to take into account the atmosphere above the balloon and its attenuating influence on the incident X-rays. This information, along with the data from the telescope, are continuously transmitted to base by telemetry. To maintain redundancy, the



An orientated balloon-borne X-ray telescope designed and produced at the TIFR.

data is also recorded on photographic film and recovered with the payload. Payload recovery can be among the most frustrating parts of the entire experiment, particularly when the balloon drifts out to sea. At times like these, telemetry prevents the experiment from becoming a total loss.

Covering the achievements to date, Professor B. V. Sreekantan of the Tata Institute's Department of Astronomy stated that in the brief period this programme has been under way, the TIFR has obtained some interesting results in balloon-based X-ray astronomy. While few sources have been discovered through balloons, two of these had been observed through TIFR experiments in 1969. These weak, hard X-ray sources have been designated TWX-1 and TWX-2. He added that these were later confirmed through experiments by the Institute, while one of them was also observed by the Uhuru satellite.

Short-term Variations in Sco X-1

Another interesting observation was of short-term variations in the intensity of Sco X-1. These sudden increases in the intensity of hard X-rays are believed to have been caused by very large flares on these stars. In collaboration with the Institute of Space and Aeronautical Science, University of Tokyo, the Nagoya University, and Hyderabad's Nizamiah Observatory, the TIFR had undertaken simultaneous studies on the intensity variations of Sco X-1 in both the hard X-ray and optical parts of the spectrum. The X-ray band was covered by a TIFR balloon launched on 5 May 1971. The experiments noted positive correlation between the two emissions. They found that the intensity of X-rays increased with the sources' optical intensity.

Studies have also been undertaken of the diffuse background radiation in the energy range of 20-200 keV. Such information is vital for cosmological studies like the origin of the Universe and the nature of intergalactic matter. Professor Sreekantan had participated in some of these experiments under Professor Bruno Rossi of the MIT during 1965-67. He was part of the large international group which undertook the experiments in association with American scientists and engineers, leading to the accurate location of Sco X-1 and its subsequent identification with a flickering, intensely blue star of 13th magnitude.

Two very important balloon-borne X-ray astronomy payloads were launched from Hyderabad on 30 November 1974, in collaboration with Japanese scientists. At about midnight on that day, the Crab nebula was occulted by the Moon – and the occasion was utilised for a wide range of experiments all over the world.

Rocket Astronomy

More recently, the field of rocket astronomy has claimed the interest of TIFR scientists. This work is headed by Professor S. Naranan who was earlier associated with cosmic ray studies. He had worked for a year each in this field at the MIT and the American Science and Engineering Inc., and had also participated in some aspects of payload design for the Uhuru satellite.

Explaining the difference between balloon and rocket techniques, Professor Naranan stated that while rockets typically have an observation time of 5 min., that for balloons is 5 to 6 hours. The latter also have many times the payload capacity of the small rockets available in India. On the other hand, he pointed out, only hard X-rays penetrate down to balloon altitudes and since most sources are abundant only

in soft X-rays, the balloon instrument has to have high sensitivity. Similarly, rockets are unsuitable for hard X-ray studies as these sources are usually so weak that they require far longer observation periods than are possible with rockets. Even the study in soft X-rays is limited to very bright sources because of the rocket's very brief observation time. Thus balloons and rockets are complimentary rather than competitive.

The most rewarding work in rocket X-ray astronomy is hereafter likely to be in the ultrasoft region below 2 keV, where little work has been done to date. Much has already been achieved in the region beyond 2 keV with stabilised payloads, and the Uhuru satellite, which discovered 165 sources in the 2-6 keV range, has made rockets virtually obsolete for the study of harder X-ray emissions.

By contrast, except for a small aperture focusing telescope carried by the Copernicus satellite, no soft X-ray instruments have been placed in to orbit, though large-area detectors are scheduled to be launched this year. Compared to the 165 X-ray sources located by Uhuru, only about 20 discrete soft X-ray sources have been observed to date – mainly through rockets. Spectral data is available for less than half of these. Serious discrepancies exist among the few experiments undertaken to date.

Among the important X-ray sources to be studied below 2 keV are supernova remnants (SNR) – the leftovers of cataclysmic stellar explosions in which the stars involved are completely demolished. Such events occur in our Galaxy only about once in 100 years, and a rocket would be totally inadequate for studying the initial event. As the event evolves through various stages over thousands of years, these could be studied by rocket-borne instruments.

Actually, SNR's are far more easily observed in the radio region and about 100 have already been identified by radio-astronomers, in our own Galaxy. Of these, only about half a dozen have been found to emit X-rays – just three of them beyond 2 keV. It is anticipated that most of the others must be emitting soft X-rays at less than 2 keV. This region has not been well explored to date because of instrumentation difficulties. The diffuse X-ray background in the sub-keV region also needs to be mapped, and the sky survey is far from complete.

The Physical Research Laboratory, Ahmedabad, has also been undertaking balloon and rocket based experiments in X-ray astronomy. A number of proportional counters, mounted normal to the spin axes of the rockets, have been launched to high altitudes to view a narrow band in the celestial sky along the rocket's horizon. The PRL has launched Nike-Apache rockets from Thumba and also participated in firings from the Kagoshima Space Centre in Japan on a collaborative basis.

Was Con X-2 a Nova?

Among the interesting results obtained from these experiments was the observation of low energy X-ray flux from the source Con X-2 after its reported extinction in May 1967. This observation was of great astrophysical significance and indicates that Con X-2 may be a nova.

Sco X-1, the most powerful X-ray source, has been studied in great detail. Analysis of the optical data from that source indicates that apart from the usual flare type variations, Sco X-1 has long-term periodic variations, of about 2 to 3 hours period, similar to those observed in radio emissions from that object. PRL scientists have observed that simple relationships exist between the source's temperature, density and size, and believe it to be a white dwarf type star of only about solar mass.

In 1969, Rappaport, Bradt and Meyer had suggested that soft X-ray observations of the Crab nebula could provide information on the density and composition of the interstellar gas, since the distance of the source and its energy spectrum above 2 keV had been well established. They had obtained an average interstellar density of 0.5 H atoms/cm^3, assuming that the distance to the Crab nebula was 2 kiloparsec. Since then, other groups have also measured the soft X-ray spectrum of the Crab nebula, with varying results.

Early last year, Professors S. Naranan, B. V. Sreekantan, and V. S. Iyengar of the TIFR's Cosmic Ray Group undertook a rocket-based experiment using for the first time a payload designed and produced entirely in India. To avoid duplication of the large amount of earlier work in other countries, notably the United States, in which they themselves had participated, these scientists decided to cover the largely unexplored X-ray energy band 0.5 to 10 keV, concentrating on the low energy region ($<$1 keV) using thin-window, large-area proportional counters.

Apart from the Crab, the group also measured the low energy spectrum of Sco X-1, Nor X-1 and Nor X-2 in the 0.5 to 10 keV energy range. The payload was launched from Thumba (latitude 8°32'N, longitude 76°51'E).

Proportional counters used in the past employed either thin berylium or mylar windows, and were only sensitive to the narrow energy band, 1-10 keV. Because of their low resolution and limited dynamic range, good spectral data had been obtained only for a few bright sources like Sco X-1, with very little data for sources below 1 keV.

Similarly, data on the diffuse cosmic ray background below 1 keV obtained until now has been contradictory. Such soft X-ray observations are of very great astrophysical importance for a better understanding of factors like the density, distribution and composition of interstellar and intergalactic space. It was for these reasons that the TIFR scientists decided to concentrate on studies of discrete sources as well as the cosmic background radiation in the very soft X-ray region below 1 keV.

The TIFR detectors consisted of two banks of gas proportional counters, each with an effective area of 125 cm^2, mounted back to back. They had very thin aluminium coated windows and a 90 per cent argon – 10 per cent methane gas mixture maintained at one atmosphere pressure. These windows had a peak transmission efficiency of 28 per cent compared to only 15 per cent efficiency for a mylar window of only 3.2 microns.

Maintaining this high pressure at altitude is a major problem with thin film counters and that is the major reason for such payloads not being employed at satellite altitudes where the pressure differential is, of course, much higher. Further, the atmospheric absorption of soft X-rays at 0.25 keV in the horizontal direction is so high at altitudes below 120 km that these readings have to be taken above that altitude.

The Centaure IIA, used for this experiment, has no attitude control system and is therefore spin-stabilised. For undertaking a sky survey of discrete X-ray sources and the X-ray background radiation, the hexagonal collimators of the X-ray detectors were elevated 10° above the normal to the spin axis so as to scan a small circle in the sky, almost normal to the longitudinal axis as the rocket spins. Thus the X-ray sky was scanned just above the rocket horizon.

Two-stage Centaure IIA (C.09) rocket with soft X-ray payload on the launch pad at Thumba (South India) before the highly successful experiment.

The X-ray astronomy payload of the Centaure IIA consisting of (top to bottom): 1. triaxial fluxgate magnetometer; 2. electronics package; 3. two banks of gas-filled proportional counters; 4. a cylindrical container with rocket instrumentation.

A major advantage of Thumba's location close to the Equator is that it minimises the effects of low energy electrons scattered from the Van Allen radiation belts. Similarly, because of the high geomagnetic cut-off, the cosmic ray background and gamma rays produced in the atmosphere are of minimum intensity near the Equator; also, to eliminate the albedo and fluorescent X-rays from the atmosphere due to solar X-rays, the flight was undertaken at night.

The Centaure IIA reached an altitude of 165 km and was above 120 km for 196 sec. It was spin-stabilised at 4.5 r.p.s. The most significant feature of the rocket's performance was its extremely low precession throughout the flight – the semi-angle of the precession cone being less than 2°. Thus data obtained from successive spin cycles was superimposed.

Density of Interstellar Matter

The experiment proved to be far more successful than had been anticipated and gave extremely valuable data. By far the most important result was the density of the interstellar matter in the direction of the Crab nebula. Obtained from the absorption of X-rays below 1 keV by interstellar gas, it corresponds to 0.5 H atoms/cm^3. This is in good agreement with some of the earlier ultraviolet measurements obtained by satellites, but is a factor of two higher than the figure deduced from 21 cm radio observations. The interstellar hydrogen column density in the direction of the Crab was found to be 3×10^{21} H atoms/cm^3. Further, on the basis of current models on density and composition of interstellar dust, the absorption of soft X-rays from the Crab was found to be predominantly due to interstellar gas.

Future Plans

Observation of Sco X-1 revealed that its spectrum at less than 2 keV is considerably flatter than the spectrum at higher energies. These observations gave an indication of the composition of interstellar matter. This experiment, along with earlier experiments by Indian scientists, mark only the beginnings of India's efforts in the field of space astronomy.

For the future, TIFR scientists plan to launch two improved soft X-ray payloads to scan the sky for sources in the galactic plane and in a direction normal to the galactic plane, respectively. These butane-filled counters will have larger effective areas, better angular resolution, polypropylene windows only one micron thick and having a remarkable 80 per cent efficiency and complete freedom from UV sensitivity. Counter area could be increased to as much as 2,000 cm^2 if a larger Indian-designed rocket could be utilised in place of the Centaure II. Exposure time also could be increased, thus permitting detection of fainter sources in the 0.25 keV band. Despite the lack of sophisticated equipment, Indian scientists have been able to extract quite significant results on many aspects of X-ray sources. Some day, Indian payloads stabilised about three axes will be available for more advanced research.

Of the three payloads to be carried by India's first satellite, to be launched by mid 1975 on board a Soviet Intercosmos launch vehicle, one is designed at the PRL for X-ray astronomy research. It will survey a large part of the celestial sphere in the X-ray region, utilising the spin of the satellite to scan the sky.

It would be difficult to justify expenditure on astronomy in terms of material returns on investment. It is in the enrichment of our lives and particularly of the human spirit that the best possible justification can perhaps be found. There are many who would grudge pure science its due, but if they were to have their way, the world would be an immeasurably poorer place in which to live.

REPORT FROM JUPITER – 2

By David Baker

Continued from April 1974 issue, page 144].

Through the Asteroid Belt

Pioneer 10 had been launched on its historic flight to Jupiter in the early morning hours of 2 March 1972. Accelerating away from Earth at more than 32,000 m.p.h. it had crossed the orbital path of the Moon within 12 hr. and reached the orbital radii of Mars by 25 May. Less than two months later the spacecraft had entered the asteroid belt and by mid-February was free of the suspected danger and closing on its target – Jupiter.

Much had been discovered about the asteroid belt already but the subtle variations in particle size distribution levels had to be sensed out there in the belt proper. No amount of Earth-based observation could possibly reveal the density of minute fragments at this distance. As the spacecraft emerged on the far side of the 170 million mile wide belt it confirmed the prophecies of optimists and sailed on unscathed by its encounter with the Sun's orbiting dust trap. It had found a decreasing intensity of very small particles (0.001 mm) all the way out from Earth, through the belt and beyond, whereas larger particles (0.01-0.1 mm) appeared to be evenly distributed along the path of the spacecraft. Still larger particles (0.1-1.0 mm) were found all the way out but increased threefold in the centre of the belt. Very few fragments in the >1 mm size range were observed at all.

Other findings accumulated *en route* included a better understanding of the solar wind, measurement of flow turbulence out to Jupiter, and confirmation of the paucity of galactic cosmic rays entering the inner Solar System (due to turbulence in the solar wind).

Jupiter's Great Red Spot is like a Cyclopean eye in this rectified Pioneer 11 photo made while the craft was 660,000 miles (1,100,000 km) out. The telemetry data that created the image was received on Earth at 7.23 a.m. 2 December 1974 (see page 108).

National Aeronautics and Space Administration

The Giant Planet

From Earth, Jupiter is a magnificent sight in even the smallest telescope, flanked by up to four large satellites and characterised by numerous bands following lines of planetary latitude. These bands can be divided into zones and belts, the latter exhibiting a darker appearance, with a large oval-shaped form called the Red Spot floating in the southern hemisphere. Jupiter was calculated to be more than 1,000 times the volume of Earth, with a polar diameter of 77,000 miles, but its mean density of less than 1.4 g/cm^3 gave it a mass only 318 times that of the Earth. Because of this it was believed that approximately 75% of the planet comprised the lightest gases, hydrogen and helium. Unlike any of the inner, terrestrial planets, it would have no positive line of demarcation between outer crust and external atmosphere. Instead, the tenuous layers of methane and ammonia would gradually give way to a region of liquid hydrogen beneath which lay a compressed sphere of solid, or metallic, hydrogen. Rocky silicates and other metallic elements were thought to exist in a central core of unspecified dimensions.

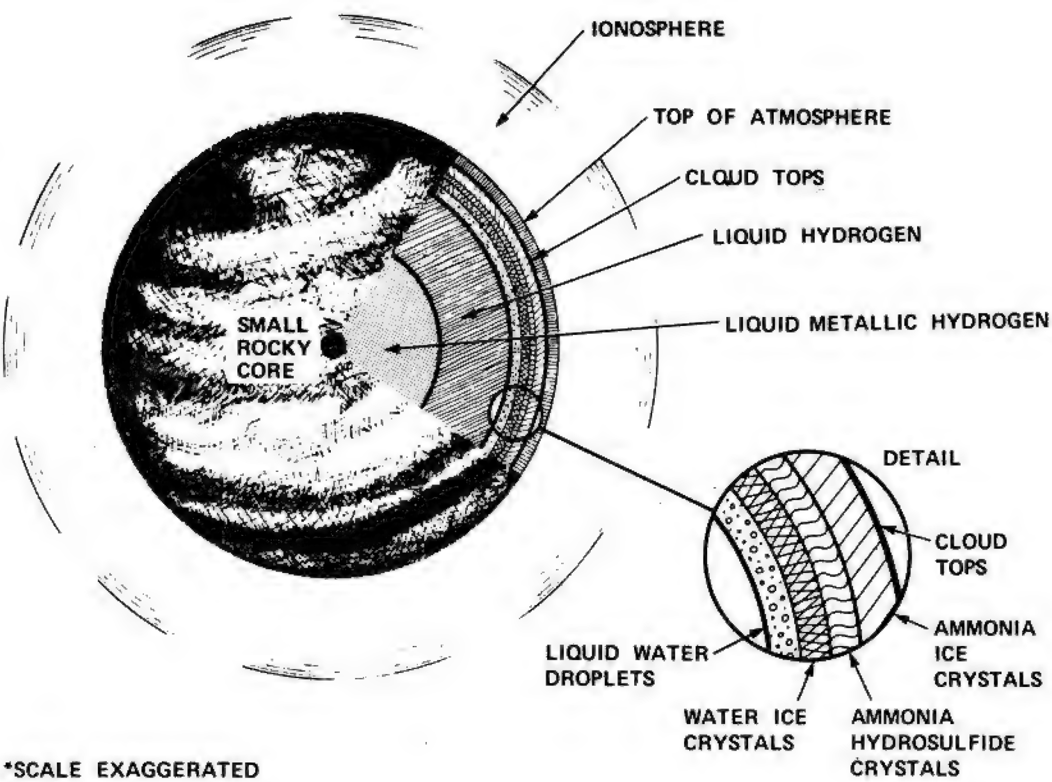
Because of the rapid rotation of the planet on its axis Jupiter exhibited considerable flattening with an equatorial diameter of 88,900 miles, nearly 12,000 miles greater than the diameter measured through the poles. Spinning with a 'surface' speed of 22,000 m.p.h., Jupiter completes one revolution in under 10 hours – faster than any other planet in the Solar System. Another unique feature of Jupiter, the largest planet of them all, is observed in the radiated energy. Nearly 2.7 times the energy received from the Sun is released from the inner regions, indicating Jupiter to be in a continual state of gravitational collapse so that it is actually radiating energy, again unlike any other planet.

Circling the Sun at a mean distance of 484 million miles Jupiter receives less than 4% of the solar energy received by the Earth and takes nearly 12 years to complete one orbit, a path inclined 1.03° to the ecliptic. In many respects the giant planet has the composition of a star, the properties of a proto-star and the structure of a planet, accounting for more than 35% of the mass of the Solar System, excluding the Sun.

The encounter sequence for Pioneer 10 was divided into five separate segments. Stage 1 began on 4 November 1973, about 30 days before periapsis at Jupiter, during which times the spacecraft sampled the transition region between the interplanetary medium and the outer region of the Jovian system. Stage 2 covered the bow shock wave created by interaction between the solar wind and the magnetic field of Jupiter, predicted to lie anywhere between 6 million and 2.3 million miles from the planet. Stage 3 would sample the outer regions of the Jovian magnetosphere from about 3 to 2 million miles from the planet. Stage 4 concerned the last 38 hours prior to periapsis and included measurements of the large inner satellites and detailed scans of the planet proper together with an analysis of particle field intensities and radiation energy levels. Stage 5 incorporated the post-encounter phase as Pioneer sped beyond Jupiter, essentially reversing the earlier sequences.

Unlike previous planetary encounters Pioneer would thread its way through the orbital radii of eleven Jovian moons; only the twelfth orbited closer to Jupiter than the encounter altitude.

Less than 26 days prior to encounter with the planet



Jupiter atmosphere model* (atmosphere depth to liquid zone approximately 1,000 km (600 miles).

All diagrams National Aeronautics and Space Administration

Pioneer 10 traversed the orbital path of Jupiter's outermost moon, Hades. Circling its parent body at a distance of 14.7 million miles, Hades marked the entrance of the spacecraft to the Jovian environment. Three days later, on 11 November 1973, Pioneer crossed the path of Andrastea, a tiny 10 mile diameter body lying more than 12.8 million miles from Jupiter. Andrastea is the innermost of Jupiter's four outer satellites. Together this quartet of moons represent maverick bodies all revolving around the primary mass in a retrograde direction at inclinations of 145° to 164°. One of these bodies, Poseidon (next to Hades), is continually perturbed and quite recently changed its inclination from 146° to 155° and varied its eccentricity from 0.291 to 0.660. Some of this irregularity is due to the fact that solar attraction can be more than 38% at apojove.

Approaching the Target

For eleven days Pioneer 10 accelerated toward Jupiter and crossed the 5.6 million mile void that separates the four outer moons from a triple nest of inner moons lying between 7.2 and 7.1 million miles from the planet. On 22 November the spacecraft traversed the orbital paths of these bodies (Demeter, Hera and Hestia), satellites with a direct motion at inclinations of 24.8° to 29°.

For the next few days Pioneer 10 continued to see the undisturbed environment of the solar wind, recording a velocity of 450 km/sec and a temperature of 10,000°K. But, like Earth, Jupiter was known to have a magnetic field of its own and predicted encounter dates for the magnetospheric bow shock wave ranged from 25 November to 1 December. Precise field intensity levels were unknown before encounter and up-wind bow shock distance estimates ranged between 5.7 and 2.4 million miles. Confirmation of the presence of a bow shock wave came at noon (PDT) on 26 November when Pioneer was 4.8 million miles from Jupiter. Solar wind velocity dropped to less than 250 km/sec and temperatures rose to more than 1 million degrees. The neutral magnetic field of the interplanetary environment oscillates around 0.5 gamma and this moved up by a factor of more than three at the transition zone. Electrons in the 106 MeV range had been detected at a distance of 18.5 million miles, undoubtedly escaping from the bow shock wave and propagating up stream in the solar wind, but at the 4.8 million mile point intensities rose 20-fold. Between 10 and 6.7 million miles electron levels were noticeably depleted but in the magnetosphere particle influx increased to a level of $10/cm^2/sec$ at a distance of 4.5 million miles.

The magnetopause was crossed at a distance from Jupiter of 4.3 million miles on 27 November. Very few trapped protons had been detected in the area between the bow shock wave and the magnetopause but at a distance from the planet of 3.5 million miles particle flux had increased 40-fold, comparable to electron fluxes. However, a rapid increase in particles of the 4-7 MeV range exhibited a 10-hour modulation, unlike the magnetic field, which oscillated between 1.5 and 8 gamma. This was due to the thermal plasma temperatures ranging between 50,000 and 100,000°K at a density of $40/cm^3$. Around Earth the magnetic field lines are predominantly responsible for holding off the solar wind but the Jovian magnetosphere contained thermal plasma four times as effective as the magnetic field in repelling the solar particles, assisted by low energy protons building up from a distance of 4 million miles on in toward the planet. It is interesting to note that Pioneer 10 had crossed the magnetopause more than 24 hours before the earliest predicted encounter.

During the early evening hours of 30 November a remarkable incident occurred. Now at a distance of only 2.4 million miles from Jupiter Pioneer 10 recorded the presence of the solar wind, measuring a velocity of 250 km/sec with high temperatures from the thermal plasma. These conditions prevailed for 11 hours until, during the morning of 1 December, the spacecraft re-entered the magnetic field of the planet, crossing the magnetopause for the second time at a distance of slightly more than 2 million miles from Jupiter.

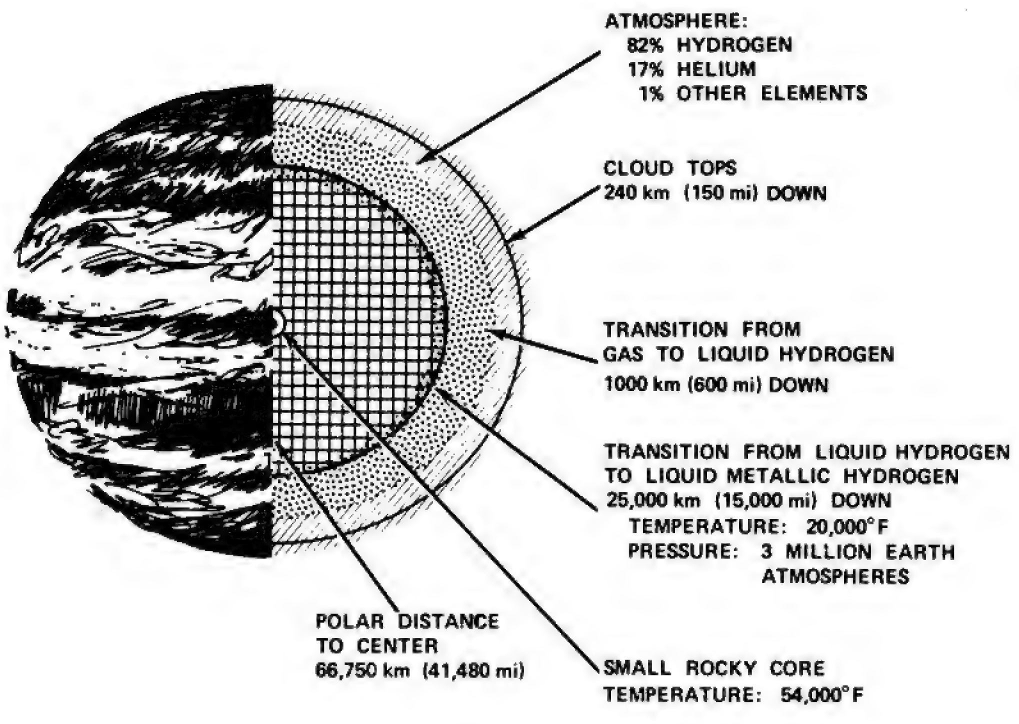
These measurements seemed to imply a massive compression of the magnetosheath, the region between the bow shock wave and the magnetopause, of nearly 2 million miles. Perhaps a surge of solar energy had arrived at the vicinity of Jupiter and pushed the magnetosphere back past the spacecraft until the magnetic field of Jupiter had reached maximum compression. To check this hypothesis an analysis was made of the scientific data from Pioneer 11, following on the heels of Pioneer 10 *en route* to Jupiter and by now half-way through the asteroid belt at a distance of 250 million miles from the Sun. The information thus displayed showed that Pioneer 11 had indeed measured a 100 km/sec increase in the velocity of the solar wind, together with a 5-fold increase in particle flux, nearly eight days earlier. This would indeed cause contraction of the magnetosphere.

The Galilean Satellites

Although Pioneer 10 had already traversed the orbital paths of seven Jovian satellites, four at a distance of 14 million miles and three at less than 13 million miles from Jupiter, the array of moons commanding major interest lay immediately ahead. At 12:26 p.m., PDT, on 2 December 1973, Pioneer 10 crossed the orbital path of Callisto, a moon as large as the planet Mercury circling Jupiter at a distance of 1.125 million miles. Exactly 16 hours later the spacecraft swept on across the orbit of Jupiter's largest moon, Ganymede, some 496,000 miles from the planet. At 10:26 a.m. on 3 December, 6 hours after crossing the orbit of Ganymede, Pioneer traversed the path of Europa, a satellite the size of Earth's moon, circling at a distance of 372,500 miles. Finally, at 2:26 p.m. the same day, the spacecraft crossed the path of Io, 221,300 miles from Jupiter.

These four Galilean satellites, so named because Galileo first discovered them with his newly acquired telescope in 1610, all exhibit characteristics suggesting a tenuous atmosphere. Callisto is unusual in that it had been known to display minor variations in brightness with orbital phase angles of $<1.5°$ but shows as much as 0.18 magnitude for solar phase angles of $\sim 10°$. Ganymede shows a variation of 0.16 in visual magnitude and virtually no colour variation, yet it is the largest moon in the Solar System. Europa, like Ganymede, appears to have water ice on its surface, a feature detected by infrared measurements. Io, by far the most interesting of Jupiter's Galilean satellites, is the most reflective object in the Solar System and exhibits a dramatic effect on decametre radiation from the planet.

Radio radiation from Jupiter was first reported in 1955 by Burke and Franklin and can be divided into three main types. Thermal emissions in the 3 cm wavelength range are induced by molecular motion in the atmosphere and decimetric transmissions (3-70 cm) come from electrons gyrating in the planetary magnetic field. But the decametric radio noise (70-60 metres) is stimulated by massive electrical discharge in the ionosphere and in 1964 Bigg reported emission modulation by Io at wavelengths above 15 metres. The source emits only when Io is between 60° and 120° from geocentric superior conjunction and the main source is greatly enhanced when the moon lies between 210° and 270°. However, quite recently Lebo has suggested a controlling influence by Europa



Interior of liquid Jupiter (planet is mainly hydrogen).

at 40 metre wavelengths. The inference regarding Io is that structural conductivity of the moon provides a link between the planet's ionosphere and the satellite for magnetic lines of force which in turn permits huge discharges of electrical energy.

Other unique characteristics of Io include its orange colouration, the surface possessing a brighter reflection in the red than any of the other three Galilean moons. Photometric studies of Io show that when it reappears after solar eclipse from behind Jupiter it has an average brightening of 0.09 magnitude, this effect decaying after 15 minutes. As no such effect is observed on entry to eclipse the inference is that Io possesses an atmosphere of methane or molecular nitrogen that freezes to the surface during occultation and evaporates to a gaseous form when heated by the Sun. Spectroscopic analysis has failed to show an atmosphere and because of this it was thought conceivable that temperature-sensitive free radicals may be present on the surface.

The closest approach of Pioneer 10 to Jupiter came at precisely 6:25:05 p.m. (PST) on 3 December 1973. Less than 16 minutes later it had passed behind Io, as viewed from Earth, and then behind the planet proper at 7:43 p.m. On its reappearance more than 1 hour later the contraction in the structure of the spacecraft due to the rapid fall in temperatures had caused a spin increase of 0.001 sec/rev but this returned to the previously measured 4.807 rpm shortly thereafter. Moving up from the southern hemisphere Pioneer 10 had crossed the Jovian equator at an angle of 14°, reaching a speed of 82,000 m.p.h. as it swept to within 81,000 miles (one planetary diameter) of the cloud tops. Precise encounter operations are detailed in the accompanying chronology.

Preparations for Jovian encounter began in earnest some five months prior to periapsis when the world-wide team of operators began repeated rehearsals and training sessions. These included simulated failures in the communications network on Earth, computer changeover in the event of a breakdown, loss of data links, loss of contact and workaround procedures for in-flight malfunction. During the actual encounter phase of mission operations some 15,000 commands were uplinked to Pioneer 10 and in view of the 92 minute transmit/return time at the distance of Jupiter and real-time command of the spacecraft broke new ground in planning problems. The operational strategy foresaw the need to turn all science instruments on well before encounter and to keep them running right through periapsis. Daily checks of pointing angle in the spin axis, changes in telemetry formats and attitude adjustments took care of the engineering requirements.

Six of Pioneer 10's scientific instruments were operated in a continuous mode, requiring little or no commands from Earth. These were, the UV photometer, the magnetometer, two of the four high-energy particle detectors, the asteroid/meteoroid telescope and the meteoroid detector. The solar wind instrument and the two remaining high-energy particle counters were calibrated several times each day and uplinked with commands to meet the changing approach conditions. The IR radiometer required several hundred commands each day, especially during the last 48 hours before periapsis, for observation of the inner satellites while the bulk of the commands went to the IPP (imaging photo-polarimeter) for views of the satellites and Jupiter itself.

With the 210 ft. dish antennae, at Goldstone, Madrid and Canberra, on hand throughout encounter Pioneer 10 was monitored by the day and night. Every 48 seconds during encounter the subsystems sent data to Earth and back-room analysts at the Ames Research Centre reviewed spacecraft status every 10 minutes. Commands were uplinked through these dish antennae (at up to 400 kilowatts transmitter power) on a frequency of 2110 MHz, while the spacecraft sent down data at the rate of 1,024 bits/sec on a frequency of 2292 MHz from its two 8-watt travelling-wave-tube amplifiers. Communication between the tracking stations and the Ames Research Centre, or Jet Propulsion Laboratory, went *via* high speed data links at up to 4,800 bits/sec.

Our New Perspective on Jupiter

Due partly to the immense volume of data returned by the scientific instruments aboard Pioneer 10 it has taken nearly a full year to reduce the information to meaningful terms and correlate measurements recorded by the first scientific survey of Jupiter. The description of that planet in the following paragraphs is as comprehensive as space will permit and readers may care to draw comparisons with earlier theories published before encounter.

The size of Jupiter has been refined to a more precise value and Pioneer 10 found the giant planet to have a polar diameter of 82,976 miles and an equatorial diameter of 88,298 miles. From the top of the atmosphere the gaseous environment gives way to a liquid region at a depth of 600 miles where temperatures reach 3,600°F. Continuing down a further 1,200 miles the temperature increases to 10,000°F at a pressure of 90,000 bars (Earth's atmospheric sea level pressure is 1.0 bar). At this point the liquid hydrogen reaches a density of 0.25 g/cm^3 (water density is 1.0 g/cm^3). At a depth of 15,000 miles from the top of the atmosphere pressure is up to 3 million bars, temperatures are 20,000°F and the liquid hydrogen gives way to metallic hydrogen.

It was Wigner and Huntington (1935) who first proposed the concept whereby any material becomes metallic at high pressures. Valence electrons are liberated from their shell by only a few electron-volts so the pressures required are of the order of megabars (1 eV = 1mbar.cm^3). Because the core potential for hydrogen is the pure Coulomb potential the properties of this element are more easily calculated than those of heavier, alkali metals. However, the non-uniform nature of electronic density brings major complications to the calculation. The theoretical zero-pressure volume of the metallic phase is 3.5 cm^3/mol H_2 but observation of the metastable phase of the low-pressure isotherm still evades detection. Although the metal is stable relative to isolated hydrogen atoms the molecular phase is more stable than the isolated atoms. If the cold metal were to decompose to molecular form the energy liberated (3 eV/mol) would leave the molecular phase at a temperature of several thousand degrees. In short, metallic hydrogen has never been observed and its presence within the deeper regions of Jupiter permits a theoretical exercise derived from known facts.

To recap, the metallised hydrogen phase begins at a depth of 15,000 miles yet there is a further 29,000 miles to the centre of the planet. It is just possible to incorporate a rocky core, albeit with very small dimensions, but temperatures are expected to reach 54,000°F and near this point some sort of hydrogen fractionation may occur. Convection currents are very much in evidence, however, and hydrogen is believed to be transported to the surface at the rate of 1,500 miles/year. This provides a core to surface transit time of from 10 to 100 years.

In the atmosphere proper, the 600 mile deep outer layer,

Pioneer 10 Event Chronology

Date	Event
Mar 2, 1972	Launch.
May 25	Crosses orbit of Mars.
Jul 15	Enters asteroid belt.
Feb 15, 1973	Exits asteroid belt.
Nov 3	Encounter phase begins.
Nov 4	First imaging by IPP of Jupiter.
Nov 8	Crosses orbit of Hades at 2.26 a.m. (14,680,000 miles out);
	Crosses orbit of Poseidon at 10.26 a.m. (14,420,000 miles out).
Nov 9	Crosses orbit of Pan at 12.26 a.m. (13,840,000 miles out).
Nov 11	Crosses orbit of Andrastea at 10.26 p.m. (12,821,000 miles out).
Nov 22	Crosses orbits of Demeter & Hera at 2.26 p.m. (7,231,000 & 7,243,000 miles out).
	Crosses orbit of Hestia at 6.26 p.m. (7,084,000 miles out).
Nov 26	Crosses bow shock wave at 12.00 p.m. (4,800,000 miles out).
	Begins 23 hr/day IPP views of Jupiter at 6.00 p.m.
Nov 27	Crosses magnetopause (4,300,000 miles out).
Nov 30	Begins first UV photometer scans (2,419,000 miles out).
	Re-entered magnetosheath (2,400,000 miles out).
Dec 1	Re-crossed magnetopause (2,100,000 miles out).
	Images exceed quality of Earth based views at 6.26p.m
Dec 2	IR views of Callisto at 7.05 a.m.
	Crosses orbit of Callisto at 12.26 p.m. (1,125,000 miles out).
Dec. 3	IR view of Ganymede.
	Closest approach to Callisto (865,200 miles) at 4.26 a.m.
	Crosses orbit of Ganymede (496,400 miles out) at 4.26 a.m.
	Closest approach to Ganymede (277,300 miles) at 5.56 a.m.
	Crosses orbit of Europa (372,500 miles out) at 10.26 a.m.
	IR views of Europa at 11.08 a.m.
	Closest approach to Europa (199,470 miles) at 11.26 a.m.
	IR view of Io at 12.38 p.m.
	Crosses orbit of Io (221,300 miles out) at 2.26 p.m.
	Closest approach to Io (221,840 miles) at 2.56 p.m.
	Begin imaging of Red Spot at 3.45 p.m. (122,000 miles out).
	IR view of Amalthea.
	Periapsis at 6.25.05 p.m. (81,000 miles out).
	Crosses Jovian equatorial plane at 6.36 p.m.
	Io occultation at 6.41 p.m., exits at 6.42 p.m.
	Enters Jovian occultation at 7.43 p.m., exits at 8.43 p.m.
	Enters planet's shadow at 8.19 p.m., exits at 8.59p.m.
Dec 4	948,256 miles from Jupiter at 6.25 p.m.
Dec 6	2,313,000 miles from Jupiter at 6.25 p.m.
Dec 8	3,508,000 miles from Jupiter at 6.25 p.m.
Dec 10	4,633,000 miles from Jupiter at 6.25 p.m.
	Exits magnetosphere, enters magnetosheath.
Dec 12	Crosses bow shock wave, enter solar wind.
Dec 13	Solar wind pressure places Pioneer back in magnetosphere.
Dec 18	Final exit from magnetosphere and bow shock wave.
Jan 2, 1974	Encounter phase ends.
Mar 1976	Crosses orbit of Saturn.
Aug 1979	Crosses orbit of Uranus.
Apr 1983	Crosses orbit of Neptune.
1987	Crosses aphelion of Pluto's orbit. Reaches Aldebaran after 8 million years.

Note: All times are Pacific Standard Time.

gaseous composition is made up of 82% hydrogen, 17% helium and 1% other elements. It accounts for just 1% of total planetary mass and consists of four layers. The uppermost layer is formed of ammonia ice crystals at a pressure of 0.7 bar and a temperature of -184°F. Beneath this lies a zone of red-brown ammonia hydrosulphide crystals, underlain by water ice crystals. The deepest layer is composed of liquid water droplets with ammonia in solution. About 140 miles below the top of the atmosphere, where methane and ammonia is evidently in great abundance, pressures are 0.3 bar at a temperature of -229°F. Above this inversion layer, at a point where pressure equals 0.1 bar and temperatures are -247°F, lies a haze layer of aerosols and hydrocarbons (ethane and acetylene). The ionosphere extends a further 1,800 miles out into space.

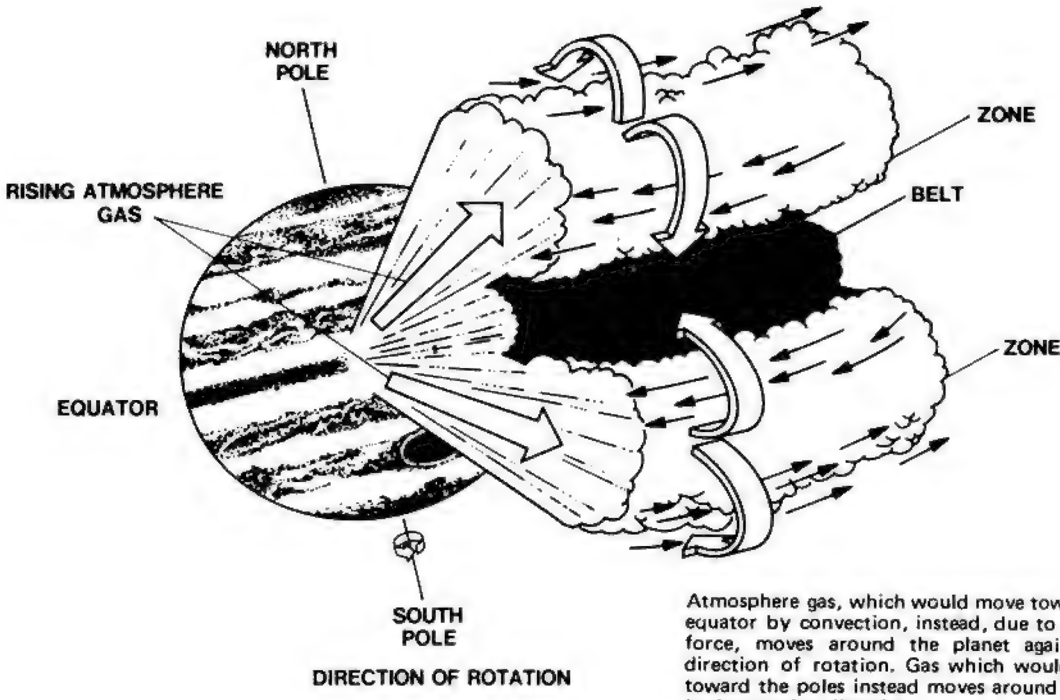
The permanent belts of dark bands and lighter zones that girdle the planet demonstrate the convective nature of the atmosphere. The zones, 12 miles higher than the belts, are warm convective cells while the belts are descending currents of cooler gas. Currents which on Earth would move toward the poles from the tropics spiral round the planet in the anticlockwise direction normal to the rotation of Jupiter on its axis. Those gases which would move toward the equator by convection drift round the planet against the direction of rotation. Moving in opposing directions due to the coriolis effect these north and south sub-divisions of the zonal belts create 360 m.p.h. winds with the tops of the warm zones 15°F cooler than the dark belts. The Red Spot, visible for several centuries, is now thought to be the vortex of an intense storm rigidised by rapid circulation. It is 25,000 miles long, 8,000 miles wide and 5 miles above the surrounding cloud deck. Several other minor storms of similar nature are visible on the photo' images.

The Radiation Belts

Moving from the planet to its stimulated environment, Jupiter has inner and outer magnetic fields which exhibit unique characteristics. The inner field extends 800,000 miles above the cloud tops with a field strength varying from 3 to 10 gauss (Earth's field at the surface is 0.35 gauss, or 35,000 gamma). The inner field is tilted 10° to the planet's equator with a centre 1,320 miles north of the geometric centre and offset 4,840 miles on a line parallel to the equator. Because of this the field appears to wobble 20° in latitude.

The outer field extends from 2.1 to 6.5 million miles above the cloud tops. In total the Jovian magnetic fields contain a total energy 400 million times that found within the Earth's magnetic field. The radiation belts girding the planet conform to these fields and the inner belt forms a doughnut-shaped ring extending 800,000 miles from the ionosphere, tilted 10° to the equatorial plane. Radiation levels decline rapidly with magnetic latitude and intensity falls by an order of 10 in 40° of latitude. Electron intensity appeared to increase as distance to the planet was reduced,

Jupiter weather.



Atmosphere gas, which would move toward the equator by convection, instead, due to coriolis force, moves around the planet against the direction of rotation. Gas which would move toward the poles instead moves around Jupiter in the rotation direction. .

with a peak level of 1,000 million electrons/cm^2 at the periapsis altitude of 81,000 miles. Approximately 90% are in the 3-30 MeV energy range.

Proton density appeared to peak at a distance of 114,000 miles from the planet, declining with decreasing distance. Maximum density was 70 million protons/cm^2 in the $>$35 MeV range, a somewhat lower value than expected in the vicinity of the liquid hydrogen planet. Protons are, of course, the atomic nuclei of hydrogen. Electron and proton densities are 10,000 and 3,000 times the peak levels in Earth's orbit respectively and total radiation is 100 times the lethal dose for humans.

The outer radiation belt conforms to the outer magnetic field, extending between 1.3 and 6 million miles beyond the inner belt with a thickness of 445,000 miles. Within this belt lies a zone of high intensity radiation forming a thin sheet bisecting the outer belt horizontally. Electron intensity reached a maximum 3 million particles/cm^2 ($>$60 KeV) while proton intensity was measured at 500,000 particles/cm^2 (0.5 MeV). Thus, the inner field is tilted 10° to the planet's equator while the outer field is in plane with this line.

The inner magnetosphere has a mean diameter of 1.8 million miles while the outer field pulsates with a diameter of 4.4 to 13.2 million miles according to the strength of the solar wind. The outer field contains a particle sheet electrified by ionisation producing a magnetic field of 5 gamma. High energy particles are stretched along the magnetic lines and spun off upwind of the solar particles. Pioneer 10 first sensed these particles 140 million miles up-Sun of Jupiter although it would appear that other particles have been measured in the vicinity of Earth. This means that Jupiter is the only planet in the Solar System to be a source of high-energy particles.

If it were visible to the naked eye from Earth the magnetosphere would occupy a region of the sky four times that of the solar disk and the magnetic tail is expected to reach the orbital radii of Saturn, a distance equal to that separating Jupiter from the Sun. These enormous belts are 100 times the diameter of those around Earth and 1 million times larger in volume. The bow shock wave, the interface of the magnetosheath with the solar wind, has a diameter of up to 16.5 million miles and represents a distance equal to half the mileage separating Mars from Earth at closest approach.

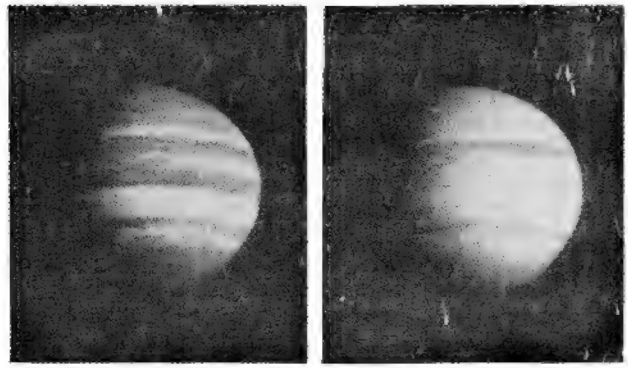
Of Jupiter's moons, Io was found to have the highest density at 3.5 g/cm^3 with an atmosphere of hydrogen, nitrogen and sodium. Next comes Europa with a density of 3.14 g/cm^3 and Ganymede at 1.94 g/cm^3. This satellite, largest in the Solar System, has an atmosphere similar to Io with a detectable ionosphere and surface markings similar to highland and maria regions on the Moon. Callisto was found to have a density of 1.62 g/cm^3. An interesting feature of Io was the hydrogen cloud extending around one-third of the orbital radius. This has never been seen before.

Altogether, Jupiter presents a formidable prospect for even the unmanned spacecraft. Manned expeditions to the Galilean satellites may be prohibited by the intense radiation and it is doubtful if a human being will ever get as close as Amalthea, the inner moon lying well within the periapsis altitude of Pioneer 10. December 2 1973, is a unique landmark in the exploration of the Solar System. In achieving such a successful encounter with the Sun's largest companion Pioneer served as fitting precursor to its sister-ship Pioneer 11 and the follow-on Mariners due for encounter with Jupiter in 1979.

SPACE REPORT

A regular monthly review of Space Events and Technical Trends

TRIUMPH OF PIONEER 11



Jupiter's moon Io is faintly seen over the north pole of Jupiter in this rectified version of a Pioneer 11 image made on the day before the close encounter. Pioneer was still more than a million miles away. Photo at left shows blue light reflected from the planet, and the right photo shows red.

National Aeronautics and Space Administration

A precarious journey of 620 million miles reached a climax on 3 December 1974, when America's Pioneer 11 spacecraft swept under the South Pole of the giant planet Jupiter, sped through fierce radiation belts and was flung over Jupiter's North Pole and back across the Solar System toward Saturn, writes USIS Science correspondent Everly Driscoll. The closest approach to the planet occurred at 12:22 a.m. EST (1722 GMT) when the space probe passed within 26,600 miles of Jupiter – three times closer than the pass of its sister craft, Pioneer 10, a year before. The craft was travelling at a speed of 107,000 miles-an-hour – the highest speed ever achieved by a man-made object. Because its pass by the giant planet was closer, the spacecraft received radiation doses ten times higher than those encountered by Pioneer 10 and 40,000 times greater than radiation in Earth's Van Allen belts.

But since the spacecraft was moving so rapidly, it survived, so bearing out the earlier expressed confidence of Dr. John H. Wolfe, Pioneer project scientist, at NASA's Ames Research Center in Mountain View, California.

Before its dramatic survival Pioneer 11 had already taken more than 130 pictures of Jupiter and focused its imaging system and ultraviolet photometer on Callisto, Ganymede, and Europa, three of Jupiter's 13 moons *(the thirteenth moon of Jupiter was discovered last September by an American astronomer Ed.).*

The pictures reveal that Callisto has a small but well-defined south polar cap. The new pictures of Jupiter also show changes in the structures of clouds near the giant red spot since last year.

Pioneer 11 focused its instruments also on Amalthea, the innermost moon of Jupiter, and Io, the second moon out from Jupiter. Io, a little larger than Earth's moon, has been of special interest to U.S. astronomers now for about ten years since it was discovered that Io affects low-frequency radio waves from Jupiter. Io appears to have sodium on its surface and Pioneer 10 verified that Io has an atmosphere, making it the smallest known object in the Solar System with an atmosphere. Io has a density a little greater than Earth's Moon which means it is probably composed of rock.

Scientists have verified with Pioneer 11 results some of the observations of Pioneer 10. One such result is the escape of radiation from Jupiter's magnetic field. The radiation had been viewed from Earth's orbit now for several years, but scientists were unaware of the source. Now as a result of Pioneer 10 and preliminary results from Pioneer 11, Dr. John Simpson of the University of Chicago says he is fairly confident that the bursts are leaking out from Jupiter's field. How this radiation escapes the field, however, is not yet understood.

Scientists also hope results from Pioneer 11 will lead to a better understanding of Jupiter's weather, atmosphere and interior. Those from Pioneer 10 support the theory that Jupiter, the largest planet in the solar system, is a spinning ball of liquid hydrogen without any detectable solid surface. If it has a core at all, it is small, buried more than 41,000 miles deep in the interior.

From ground-based observations and from Pioneer 10 data, scientists know Jupiter is mostly hydrogen and helium. Methane and ammonia have been observed in the clouds. The grey-white zones that band Jupiter are cloud ridges of rising atmosphere looming twelve miles above the cloud belts, the darker bands. These orange-brown belts then are cloud troughs of descending atmosphere, 12 miles deep.

Pioneer 10 data do not explain the composition of Jupiter's red spot, but they do indicate that the spot towers some five miles above the surrounding cloud deck. It is now thought this spot is the vortex of an intense storm, hundreds of years old, a 25,000 mile wide mass of whirling clouds. Pioneer 10 pictures also revealed other, smaller red spots in the Jovian atmosphere.

Jupiter's atmospheric circulation patterns are far different from Earth's. Instead of the circular cyclone and hurricane-type storms on Earth, the clouds of Jupiter are stretched around the planet. Heat rising from the interior of Jupiter brings gas up. Jupiter's fast rotation rate (22,000 m.p.h.) then "stretches" the clouds around, creating the bands.

The passage of Pioneer 11 close to Jupiter gave scientists an even better look at Jupiter's fierce inner radiation belt. At Pioneer 10's closest approach, the radiation striking the spacecraft was already 1,000 million electrons per square centimetre per second and rising. Pioneer 11's pass three times closer made the peak level of radiation 10 times higher for a few minutes.

Since the flight path took Pioneer 11 around the planet in the opposite direction to Jupiter's rotation, scientists gained a look at Jupiter's magnetic field, radiation belt and surface during a complete revolution of the planet.

In addition to giving lessons in Meteorology, Plasma and Particle Physics, the Jupiter probes may also be of great value to biochemists who are studying the evolution of life on Earth. Jupiter's atmosphere is composed of some of the same gases – such as methane and ammonia – thought to have been present eons ago on Earth when life evolved on this planet. Biochemists have, in fact, passed electrical discharges through mixtures of methane, ammonia and water in the laboratory and produced amino acids and other precursors and ingredients of life on Earth.

Pioneer 11 could not detect amino acids or simple organisms on Jupiter, even if these organisms could survive the tumultuous conditions existing in Jupiter's atmosphere. But some of Jupiter's moons – those with solid surfaces and

atmospheres – may in fact be cauldrons for life, some biologists think.

Meanwhile, Pioneer 10 which flew by Jupiter last year, is still functioning well and taking measurements far beyond Jupiter in interplanetary space on its path out of the Solar System. After passing Jupiter, Pioneer 11 was 'whip-lashed' by Jupiter's gravity on a path which will carry it all the way back across the Solar System to Saturn – a journey of almost five years. Not only will the spacecraft be the first to fly by Saturn (perhaps between its rings), it will also be the first to chart a region of the Solar System above the plane of the ecliptic.

BRIGHTLY COLOURED MARS

The plains of Mars are orange in colour, the mountains are blue and some of the craters are bluish-green, according to photographs taken by the Soviet Mars 4 and Mars 5 space probes last spring. The first results of the processing of material sent to Earth by the spacecraft from distances of more than 200 million kilometres have been published in the journal, *Zemlya i Vselennaya.*

If the information received is corroborated by further investigation, Soviet scientists say, there is every reason for suggesting that the bottoms of some craters have a rock composition different from that of the surrounding terrain.

It was autumn in the Southern Hemisphere of Mars when Mars 5 photographed it. One of the photo's shows the winding bed of a "dry river" which had been discovered earlier. Soviet astronomers believe the feature is about 100 million years old. Photography also showed mountain ranges with peaks eight to eleven kilometres high and gentle slopes.

The atmosphere of Mars contained more water vapour than it did during the previous encounter by America's Mariner 9. This has led scientists to conclude that moisture is unevenly distributed.

A polarimeter was used to explore the photometric properties of the planet's surface. These observations supported the conclusion that the surface is covered with a layer of a crushed material.

ASTP X-RAY EXPERIMENT

One of the astronomy experiments to be performed aboard the Apollo spacecraft during the joint U.S.-USSR space mission in July may lead to a better understanding of how energy is generated. The object of the experiment, called MA-048 X-ray Observation by NASA, is to provide high-resolution celestial maps of sources and background radiation in the so-called "soft" X-ray region of the spectrum.

The information obtained could contribute to an understanding of how these X-rays emit particles such as electrons. Understanding of similar processes in the Sun contributed to the development of ways to use nuclear energy.

During Skylab, some X-ray sources were mapped but the ASTP experiment will map sources in a slightly different range. The first astronomical X-rays were discovered in 1962. To date, about 160 sources have been observed in the higher energy ranges.

In 1967 several scientists began making observations in a lower energy band and several important results were produced from these observations. First, a diffuse glow of X-rays was observed to be present in all directions of the Galaxy. But mostly toward the poles of the Milky Way galaxy. The second result was the detection of X-ray sources which emit only at low energies.

There are currently about 10 of these sources known and most appear to be associated with old supernova remnants and probably indicate the presence of hot gas plasmas produced by the shock waves from the original exploding stars. X-rays also have been observed in the Earth's auroral regions.

The ASTP experiment will complement the observations of the Uhuru X-ray astronomy satellite in a different energy range and will provide moderate resolution observations for sources which emit only in the low energy X-ray range. Principal investigator for the experiment is Dr. Herbert Friedman of the Naval Research Laboratory in Washington, DC.

CETI IN AMSTERDAM

The International Astronautical Congress held its 3rd CETI review meeting in Amsterdam on 4 October 1974. Four papers of wide ranging interest were read and discussed under the Chairmanship of Academician R. Pesek (Czechoslovakia), and the speakers manfully coped with the basic communicators problem of a defective microphone and amplifier system!

"A Survey of CETI Activities in the years 1971-1974" by R. Pesek, was, as the title implied, a discussion of the major activities directed towards CETI work during that time. The most interesting aspect in my opinion was further information on the work by Troitsky and Kardashev. This included the specific frequency bands and wavelengths used for their work: 600 MHz (50 cm), 1000 MHz (30 cm), 1875 MHz (16 cm), 3750 MHz (8 cm) and 10000 MHz (3 cm) were the main bands examined by the Troitsky team and 10000 MHz to 15000 MHz (2 cm) by Kardashev's. The antennae used by the latter group appeared to be conical tapered helices, a type particularly suited to the reception of circularly polarized signals.

Both teams are still analysing results and no further information is forthcoming as to the nature of the signals.

"Interpreting Signals from an Interstellar Probe" by A. T. Lawton described recent work on Long Delayed Echoes. Although much of the material has already appeared in *Spaceflight* and the *JBIS*, Lawton gave details of an LDE experiment carried out in December 1972, when 360 signals were transmitted at regular intervals over a 3 hour period. On the 98th transmission a possible 3 second "echo" was heard.

The Moon was below the horizon at the time, but the Trailing Lagrange Point was at an elevation of approximately 40°.

The paper then went on to discuss the power needs of a possible artifact in lunar orbit, and concluded that the waste heat radiated from such an artifact (up to 30 kw) should render it detectable in an IR survey even if it were "radio silent". Lawton expressed the opinion that the existence of such a probe was highly unlikely and that all LDE recorded to date had a natural origin. However, he did not exclude the possibility of a probe somewhere in the Solar System.

"About some manoeuvres of sub-relativistic Probes" by U. N. Zakhirov was a continuation of earlier papers read at

Baku in 1973. The paper showed that the power requirements for manoeuvring a sub-relativistic probe (travelling at up to 10% of the speed of light) were modest since the low speed allowed adequate detection and corrective action times, and the technology needed was basically that of ion engines.

"The Use of Neutrinos for Interstellar Communication" by M. Subotowiz was a highly intriguing discourse on the technological problems encountered in the process of generating, modulating collimating and transmitting these peculiar particles whose reaction with matter is so weak that they could travel over approximately 180,000 light years of hydrogen without interaction! Subotowiz then discussed the problems of detecting such particles. Our present technology demanded quite exotic apparatus (e.g. 1 cubic metre of cobalt 60 at cryogenic temperatures!). However, the weak interaction with surroundings possibly indicated a good signal-to-noise ratio, and the very difficulties outlined might possibly incline an advanced civilisation to use such means to talk to its peers with the deliberate exclusion of the humbler "peasant" civilisations using radio systems!

Needless to add these papers provoked an interesting discussion! A. C. Clarke wondered what Van der Pol would have made of such a meeting. Mr. Lawton replied that he would indeed have been interested since in the latter phase of his life Van der Pol had become involved with the subject of radio astronomy. Professor Pesek agreed and added that Van der Pol, in conjunction with his associates, had coined the term "Meta-Law" as applying to a universal code of conduct.

Professor Marx gave some details of high energy bursts of radiation received in the U.S.A. early in January 1974. Several pulses were detected in a long burst and later the detectors were saturated. The consensus of opinion was that the event signified the detonation of a supernova, the radiation being the first few seconds of the explosion. There was no evidence whatever to support the possibility of it being a CETI signal.

Marx then went on to describe what he thought was the most important aspect of probe communication, namely the ability to store and dispose of information dealing with a community which may have ceased to exist by the time the probe had arrived in a far distant solar system.

A more detailed review of the 1974 CETI meeting will appear in a forthcoming Interstellar Studies (Red Cover) issue of the JBIS. It is proposed to hold a 4th CETI review meeting this year. A.T.L.

COSMOS EXPLORES THE UNIVERSE

A high speed automatic machine, COSMOS, unveiled at the Science Research Council's Royal Observatory Edinburgh on 28 November 1974, has been developed to detect and to measure the vast numbers of faint distant galaxies recorded on photographs taken with the U.K. 48 in. Schmidt telescope which was commissioned in Australia in 1973. It has been built for the Observatory by Computer Applications Services of Heriot-Watt University and was designed jointly by scientists from both institutions.

Conceived in February 1970, COSMOS finds and measures the *Co-O*rdinates, *S*izes *M*agnitudes, *O*rientations and *S*hapes of images of stars and galaxies on the photographs at rates of up to a thousand per second. The measurements are recorded on magnetic tape and analysed in the Science Research Council's Atlas Computer Laboratory at Chilton, Didcot, Oxon.

Together with the new Schmidt telescope which combines very high quality optics with new photographic sensitising techniques to penetrate much deeper into space than any astronomical surveys have done before, COSMOS provides a powerful system for the study of distant parts of the Universe. The measurements made by the machine enable the computer automatically to distinguish galaxies from stars, and the spatial distribution and structural properties of many millions of galaxies will be determined in the coming months. Furthermore, COSMOS can make extremely precise measurements of position, size and shape of individual galaxies at rates of several hundred per hour or map them in great detail at high speed, and will be capable of measuring photographs of the spectra of the light from large numbers of both galaxies and stars.

LIFE IN THE UNIVERSE

Members of the Society who visited the John F. Kennedy Space Centre in Florida and the Marshall Space Flight Centre with the Transolar tour last autumn received a 'bonus' in the shape of a three-hour stopover in Washington during which they were able to visit the Smithsonian National Air and Space Museum. The Museum – the nation's focal point of aerospace history – contains the original Wright Flyer, Lindberg's 'Spirit of St. Louis', and the Apollo 11 command module, Columbia, among a multitude of other fascinating exhibits.

What did come as a surprise to the visitors, however, was an excellent new section entitled "Life in the Universe" which examines in the most exciting way the quest for extraterrestrial life.

This most impressive exhibition has been described by Museum Director Michael Collins – command module pilot of Apollo 11 – as "a summing up of what is known today about the Universe ... and a probe into the unknown." It condenses into four separate exhibit areas: the Universe, Life on Earth, the Solar System, and Communication with Extraterrestrial Civilizations.

The visitor enters the exhibit into a "universe" where floor-to-ceiling photographs and graphics under black light show the vastness of space and its trillions of stars.

In a special theatre, a film, "Powers of Ten" by Charles Eames, relates in a series of quantum jumps the vastness of the Universe to the minute size of the atom. Other special effects devices trace the theories of the origin and development of the Universe, its galaxies, stars, and planetary systems.

Life on Earth deals with the current knowledge of the origins and nature of life on this planet. One exhibit explains actual experiments used by Dr. Cyril Ponnamperuma of the University of Maryland, to create organic molecules in a simulated primitive Earth environment. Ponnamperuma's "recipe" is imaginatively illustrated in an 8-minute film featuring "The French Chef" Julia Child, who concocts "The Chemicals of Life."

The third section of the exhibit concerns the rest of the Solar System and man's increasing understanding of it gained from space probes and the sophisticated instruments

used by today's scientists. A feature of this portion of the exhibit is a large revolving photographic globe of Mars (one of three in the world), photomapped by Mariner 9 from orbit in 1971. There is also a reproduction of the Viking spacecraft with its orbiter and lander which will make a soft landing on Mars and search for life. Photographs and data of the most recent findings of the giant outer planets, Jupiter and Saturn, point up the possibility that they may have atmospheres like Earth's thousands of millions of years ago.

The last section of the exhibit deals with the interdisciplinary studies of cosmographers, astronomers, astrophysicists, chemists, and biologists in a field of study involved with the problems of detection of, and communication with, other intelligent life in the Universe. Students in this field of exobiology rely heavily on mathematical probabilities, based upon what is known of the Universe.

According to Melvin B. Zisfein, Deputy Director of the National Air and Space Museum and director of the exhibit, the possibility that extraterrestrial life may exist has been argued for centuries. Recently, advances in many scientific disciplines have at last provided a data base to permit exobiology to emerge as a substantial field of study.

Is there life elsewhere in the Universe? Can we find it? If we find it, how will we communicate with it? If we can communicate, what will we say? These are the questions illuminating the extraterrestrial section of the exhibit.

Part of the answer is found in the exhibit of the uses and limitations of radio telescopes which show promise at present in communicating over interstellar distances. Direct contact with other civilizations is also suggested through such devices as the Pioneer 10 space probe, presently on its way out of the Solar System. Pioneer 10 carries a message identifying its origin, which may some day be intercepted by extraterrestrials as the Earth machine flies forever through interstellar space. A replica of the metal plaque which it carries is on display. Next to it is science-fiction artist's. Donald Simpson's concept of an extraterrestrial space message which might be intercepted by earthlings. The visitor is invited either to decipher it or to push a button for the complex answer.

The extraterrestrial exhibit also includes pushbutton shows, Pick a Planet, Pick a Star, which allow visitors to manipulate various factors that create hypothetical planetary systems and hypothetical extraterrestrial life forms. The imaginary drawings of the "outer space beasts" were done by Bonnie Dalzell, a Cambridge, Massachusetts artist. A whimsical feature of the exhibit is the original mock-up of the "Starship Enterprise" used in the television show 'Star Trek'.

SOYUZ 16 MISSION

On 2 December 1974 at 09.40 GMT, the Soviet Union launched Soyuz 16 carrying a two-man crew – Commander Anatoli Filipchenko and Flight-Engineer Nikolai Rukavishnikov. Both men had flown on previous Soyuz missions, writes Gordon R. Hooper; Filipchenko as commander of Soyuz 7 in October 1969, and Rukavishnikov as Test-Engineer aboard Soyuz 10 in April 1971. The two men are the crew of the reserve ASTP Soyuz, which will be launched in the event of a technical hitch preventing the lift-off of the prime vehicle carrying Alexei Leonov and Valery Kubasov.

The flight programme of Soyuz 16, officially described as an ASTP test-flight, envisaged "the testing of the onboard equipment, modernised to answer the requirements of the joint flight, the carrying out of scientific and technological research and the observation and photography of separate sections of the Earth's surface to obtain the necessary data for solving national economic problems."

In a pre-flight interview, Filipchenko said that the flight was intended to test the new androgynous docking equipment to be used in the forthcoming ASTP flight. He said that docking tests would be effected with the help of a special imitating ring, similar to the docking ring to be carried on the Apollo Docking Module. "Technically," he said "we shall be able to use almost all docking and separation modes which Alexei Leonov and Valery Kubasov will have to use in their real flight with Apollo." He said that he and Rukavishnikov were "going to rehearse, to a certain extent, all the operations which are to be carried out in July 1975."

By 19.00 GMT on 2 December, Soyuz 16 had completed 5 revolutions of the Earth. During the 5th revolution, a trajectory correction placed the spacecraft in an orbit with the parameters of 177 x 223 km x 223 km x 51.8° x 88.4 minutes. From 19.30 GMT 2 December to 03.30 GMT 3 December, the crew were outside the Soviet zone of radio visibility. American controllers at JSC, Houston, had begun tracking the Soyuz 16 spacecraft immediately after the Russians advised them of the launch. "The Russians had promised us this practice run," said one controller "but we didn't know when it would be until the phone rang."

After approximately 24 hours in orbit, Soyuz 16 had completed 16 revolutions. The crew began their second working day on 3 December after having breakfast and making medical checks, which showed that both men were in good health, with normal pulse and respiration. During the day, the crew carried out two major experiments. The first was to reduce the Soyuz capsule's pressure from 14.72 lb./sq. in. (760 mm) to approximately 10 lb./sq. in. (530 mm), and raise the oxygen level from 20% to 40%. The normal Soyuz capsule atmosphere is composed of an oxygen-nitrogen mixture. By adjusting the atmosphere in this way, halfway towards the 5 lb./sq. in. (approximately 265 mm) pure oxygen atmosphere of the Apollo spacecraft, the transfer time needed to be spent in the Docking Module during the ASTP mission will be reduced from approximately 2 hours to 1 hour.

The second major experiment was the simulation of the Apollo lift-off carried out by the crew. The Soyuz 16 orbit was changed to a circular one during the 17th and 18th revolutions. The new orbit, with the parameters 225 x 225 km x 51.8° x 88.9 minutes, is the one the ASTP Soyuz will use. (The actual docking will be carried out when both spacecraft have moved to a 222 x 222 km orbit.) Once this orbit had been achieved, the crew gave the mock "go-ahead" signal to the Apollo crew. Exactly 7½ hours after the beginning of the exercise, the Soyuz was flying over the Cape Canaveral launch complex. During the ASTP mission, the Apollo is due to be launched 7 hours 22 minutes 46 seconds after the Soyuz launch, providing the Soyuz is functioning normally, and the crew give the go-ahead for the launch. The ground control personnel at the Gagarin Space Flight Centre in Kalinin, near Moscow, fully rehearsed the Apollo lift-off. An electronic sign which read "Apollo activated" was switched on in part of the control room's display panel.

Also on 3 December, Konstantin Bushuyev, the ASTP

Russian Technical Director, revealed the main design changes made in the Soyuz for the joint flight, and being tested onboard Soyuz 16. The Soyuz carries an improved life-support system and additional air regeneration blocks, the new androgynous docking system, a modernised power supply system, and a modernised motion control system. Additional equipment has also been installed, for example, impulse beacons and signal lights which will aid the Apollo crew in locating and docking with the Soyuz.

The Soyuz 16 crew began their third working day on 4 December. They broadcast several TV transmissions to Earth and tested new onboard systems. Also they continued medical and biological experiments, including the observation of the nature of zone formation of ray fungi. One of their research tasks was the study of microbe exchange between the cosmonauts during a space flight. Control probes of the microbe fauna on the cosmonauts,skin and mucous membrane were taken every day. This experiment as well as the zone-forming fungi experiment, are included in the ASTP flight.

Also on 4 December, the crew completed preliminary trials to test the androgynous docking unit. Bushuyev announced that a full dress rehearsal of the ASTP link-up would follow, using a special 44 lb. (20 kg) metal ring, which imitated the Apollo docking ring.

On 5 December, *Tass* announced that Soyuz 16 had passed the half way point in its mission. The crew spent most of the day carrying out docking tests. They simulated 11 modes of operation, with the main ones being repeated several times. A total of 20 operations were carried out, with only half the allotted time needed. The imitating ring was pulled towards the Soyuz docking mechanism with a force equivalent to the Apollo's mass. This made it possible to completely simulate the engagement and linking-up of the ships. The electric drives were loaded to the designed capacity of 2 tons per link-up element. As expected, all the mechanical operations were performed more quickly than on Earth.

The docking tests carried out by Soyuz 16 coincided with the announcement that an American group of ASTP technicians in Moscow had completed 2 months of ground tests on the docking mechanism. They reported that the system had worked without a hitch.

On 6 December, the Soyuz 16 crew appeared on Russian TV, and showed viewers around their spacecraft. They proudly pointed out a flag and badges of the Young Communist League which decorated a bulkhead of the spacecraft. During the transmission, Filipchenko announced: "Our experiments have come to an end and soon we shall start to pack." Both cosmonauts were reported to be well.

Also during the day, they completed a series of docking tests which "went without any hitches." They also completed their experiments with microbes and plants, and continued with their observations of the growth of micro-organisms.

On 7 December, *Tass* merely repeated that the Soyuz 16 crew was preparing to return to Earth after completing their experiments.

On 8 December, the spacecraft made a successful re-entry, and touched down at 08.04 GMT in Northern Kazakhstan, approximately 300 km north of Dzhezkazgan. During the mission, which had lasted 5 days 22 hours and 24 minutes, the crew had made over 96 revolutions of the Earth. Five minutes after touchdown, Bushuyev got on the hotline to JSC to inform Glynn Lunney, his American counterpart, of the successful conclusion of the flight, and its preliminary results.

The preparations for touchdown were monitored by the Kettering Group, and they announced the touchdown half-an hour before the official Russian communique. They had also been the first with the news of the launch.

The general impression given by the Russians was that the mission had been an outstanding success. Alexei Yeliseyev, the ASTP and Soyuz 16 flight director, said that the flight control was up to the mark. All control systems which are to be used during the ASTP flight were tested during the Soyuz 16 flight, with the exception of the group involved with the inter-control centre communications. The technicians and engineers involved at JSC and Kalinin will undergo conclusive training at the beginning of 1975.

General Shatalov, in charge of cosmonaut training, said the crew had not committed a single error, and had worked smoothly and efficiently throughout the flight. Ground control had only one complaint, and that was that on one occasion, the crew had woken up at 06.00 instead of taking their full sleep quota. Shatalov also revealed that Soyuz 16 had not been the first test of ASTP systems. Two Cosmos satellites had been launched in the summer of 1974, and the US had been fully informed of the results. An examination of Cosmos launches reveals that the only two satellites inserted into an orbit with parameters similar to those of the ASTP orbit are:-

(a) Cosmos 652: launched May 15, 1974 into an orbit with the parameters 180 x 362 km x 51.8° x 89.6 minutes.

(b) Cosmos 672: launched August 12, 1974 into an orbit with the parameters 198 x 239 km x 51.8° x 88.6 minutes.

The success of Soyuz 16 as an ASTP rehearsal has been strongly emphasized by the Russians. In a TV interview, Alexei Leonov, the Commander of the ASTP Soyuz, said that the success of the flight "opens the door for the joint venture." And Konstantin Bushuyev said that Soyuz 16 had "succeeded in checking the whole complex of new systems and units responsible for the success of the future link-up of Soviet and US spacecraft." He said he was confident that "the Soyuz 16 logbook will be our textbook during the last preparations for this important international experiment."

The Soyuz 16 crew, Filipchenko and Rukavishnikov, returned to Star Town on 10 December and placed the traditional wreath on the monument to Yuri Gagarin. Both men were subsequently made Heroes of the Soviet Union, both for the second time.

LUNA 23

The Soviet moon probe Luna 23 landed, as planned, in the Sea of Crises on 9 November, but only part of its intended programme could be carried out. The craft came down in a rugged area in the south of the region, with the result that a drilling device attached to it was damaged. This frustrated an attempt to obtain rock samples for analysis.

The research programme of Luna 23 had to be replanned and a modified three-day programme was then carried out satisfactorily.

Russia's first robot soil sampler crashed on the Sea of Crises (approximately 17°N, 60°E) on 21 July 1969 just one day after the Apollo 11 astronauts had landed in the Sea of Tranquillity. Subsequently, Luna 16 obtained a 100 gramme (under 4 oz) 35 cm long core sample from the Sea of Fertility in September 1970. Luna 20 landed in a mountainous region between the Sea of Fertility and the Sea of Crises in February 1972, obtaining a sample of similar proportions.

MARS PROBES STAMP

The Soviet Ministry of Communications has issued a new postage stamp commemorating the multiple launch of the automatic interplanetary stations Mars 4 and 5 and Mars 6 and 7. The multi-colour miniature includes a globe with the outlines of mainland features.

WEIGHING A STELLAR CLUSTER

The black hole "closest to the Earth," a giant clot of matter radiating neither light nor radio waves, has been detected by Soviet astronomers. The enigmatic super-dense formation is at several light years' distance in the centre of the globular cluster Omega in the constellation of Centaurus.

The inference was made after Professor Kirill Ogorodnikov and his assistant Elena Naumova, astronomers of Leningrad University, "weighed up" anew the Omega Centauri globular cluster and determined with great accuracy its mass, which they suggest is a million million times that of the Sun.

The astronomers used their own mathematical method to determine the mass based on an interaction effect between the gravitational fields of globular clusters and neighbourhood stars. It appeared that not only do such stars change their trajectory but also their velocity. Such infinitisimal perturbations have made it possible to define by computer the mass of the globular clusters.

The mass value as defined by the astronomers for the Omega Centauri cluster exceeds former estimates by a factor of one thousand. This cannot be accounted for alone by the density of all the visible stars in the cluster.

SOLID STATE RECORDER

A solid state NASA-developed data recorder with no moving parts may replace magnetic tape recorders aboard spacecraft in the 1980's. Other possible applications include use as aircraft flight data recorders and as electronic control systems in mass transit systems. Experimental models of the device have already been pronounced successful.

According to Charles E. Pontious of the Office of Aeronautics and Space Technology, these recorders offer high reliability – a major advantage over magnetic tape recorders. Failure of moving parts accounts for 70 per cent of magnetic tape recorder malfunctions aboard spacecraft and elimination of moving mechanical parts could be expected to result in very much greater reliability.

Deep space exploration requires systems onboard the spacecraft capable of reliable operation for 1-10 years or longer. A solid state data storage system provides the potential for meeting these needs.

Technology for such a recorder is based upon the use of very small magnetic domains or spots termed "bubbles". These magnetic bubbles exist in specially prepared garnet chips. By applying a thin film of magnetic material in appropriate patterns over the chips, these bubbles can be moved and controlled to perform logic functions.

Each chip has a capacity for a certain number of bits of information, determined by the number of magnetic bubbles that fit within a chip. This concept of using movable bubbles is relatively new and is known as "bubble technology".

The present experimental model has a 60-thousand bit data storage capacity. The overall objective of the present research programme is to provide a solid state data storage system with a 100-million bit capacity by 1978. If successful, flight versions of such a recorder could be ready at the end of this decade.

Management of the solid state recorder project is being carried out by the Flight Instrumentation Division at NASA's Langley Research Center at Hampton, Virginia. The memory element developer is Rockwell International.

SPACE PRODUCTS

Two products developed at Lewis Research Center have been cited by *Industrial Research Magazine* as among the 100 most significant new products developed during the last year. Selection was made by a blue-ribbon panel of technical judges out of some 1,000 entries from industries throughout the country.

The Lewis products were a new metal alloy that has super strength at white-hot temperatures and a new self-lubricating bearing material good at temperatures up to 1,650°F.

The high-strength alloy, the tensile strength of which at 2,200 deg. F. is three times that of the strongest known commercial cast nickel base alloy, is the result of joint research efforts by John C. Freche and William J. Waters of LeRC's Materials and Structures Division. It can be used where high strength at high temperature, high melting point, high impact resistance, and low cost are desired.

The self-lubricating bearing material was developed by Harold E. Sliney of LeRC's Fluid System Components Division. Its principal ingredients which permit bearings to be used at high temperatures are metal, glass, and calcium fluoride.

SHUTTLE MODEL TESTED

The Marshall Space Flight Center is conducting static firings on a small scale (6.4 per cent) model of the Space Shuttle to gather acoustical data vital to design and development activities.

The 12 ft. model's two solid engines produce a thrust of about 10,800 lb. each, while the three liquid engines produce a total thrust of about 5,000 lb. During each 20 sec. test firing, 60 acoustic measurements are taken by specialised microphones mounted inside the scale model vehicle and on the ground in the adjacent area.

Of direct concern to engineers are the acoustic environments which could induce severe structural response and

subsequent fatigue or malfunction of systems basically sensitive to high sound-pressure levels.

JUPITER'S GLITTERING MOON

The phenomenal glitter of Io, one of Jupiter's large moons, may be due to a surface rich in salt, according to a team of scientists at NASA's Jet Propulsion Laboratory. Io appears to have developed an extensive crystalline layer of sodium, much like some of the salt flats and dry lakes in the American West, Dr. Fraser P. Fanale, team leader, said. "Io's situation is somewhat analogous to that of an Earth whose oceans have evaporated except that the salts are not dominantly sodium chloride (table salt), but sulphates which dominate in the so-called "bitter" lakes of the West. Examples are Verde Valley Lake in Arizona and Soda and Searles lakes in California."

Astronomers have long regarded Io – the innermost of the four large Jovian moons discovered by Galileo – as a very odd moon. It is highly reflective, nearly as red-orange as Mars, and slightly bigger than Earth's Moon (diameter 2,262 miles and orbit distance of 262,000 miles from Jupiter). It is one of the brightest small objects in the sky, on many nights being visible with binoculars.

Sodium vapour emissions from Io were first reported in 1973 by Harvard astronomer Dr. Robert Brown. He found that a glowing cloud of sodium vapour extends 10,000 miles from Io's surface. The Pioneer 10 flyby also found a cloud of hydrogen atoms at Io.

Further closeup investigation may come in 1979, when a Mariner spacecraft flies past Jupiter carrying a telephoto lens equipped with a special filter for observing Io.

"The sodium emissions from Io are analogous to those in powerful sodium vapour lamps," Fanale says. Sodium proton sputtering at Io's poles and its interactions with Jupiter's potent magnetic field pose serious survival problems for spacecraft.

Dr. Fanale and his colleagues, Drs. Torrence V. Johnson and Dennis L. Matson, evolved their theory after employing such diverse techniques as proton beam bombardment of salt samples in a laboratory, chemical and optical analyses of meteorites, and spectral observations of Io at JPL's Table Mountain Observatory. The researchers found that the visible and infrared spectra of several salts, including salts extracted from carbonaceous meteorites, match Io's spectrum closer than materials previously suggested. (Carbonaceous meteorites are the oldest space rock yet discovered. Spectral readings are the astronomer's and chemist's means of determining elements. Each chemical component has its signature colour line).

The JPL theory appears to solve certain puzzles about Io: Why it is as bright as if it were covered by ice, yet shows no ice bands in its spectrum (while its equally bright neighbour, Europa, does); why Io has dark poles; and why it has such strong sodium emissions.

The scenario for Io's early history offered by the JPL space science team suggests that Io, unlike other Jovian satellites (there are 12, perhaps 13, in all), never had large amounts of ice. Yet it apparently was not totally devoid of water like our moon. In these respects, Io resembles Earth. It also is Earthlike in exuding gases.

As a result of internal degassing, much of Io's water seeped to the surface. Unlike the other Galilean satellites, however, the amount of water was only a small fraction of the total mass. Evaporation was rapid because of Io's proximity to Jupiter and Io's low gravity.

"Hence," Fanale says, "we claim Io uniquely developed an evaporite salt-covered surface." Europa and Ganymede, two of the other Galilean moons, still appear to have large "oceans" beneath their surface ice crusts.

The theory, he adds, explains Io's high albedo (reflective power) and absence of ice bands – and the dark reddish poles. The colouration is said to result from heavy radiation and proton reduction of salts by the highly-charged Jovian magnetospheric flux, apparently strongest at Io's poles.

The sodium-rich surface seems to be the source of the sodium vapour emissions, which pose two problems: Where does the sodium come from? Why does it glow?

The JPL team's hypothesis is that a salty surface and Jupiter's intense radiation field (similar to Earth's Van Allen belts) combine to produce the cloud. Based on the JPL proton bombardment experiments of D. B. Nash, the team believes the sodium atoms are blasted off Io's surface by the impact of this radiation with enough energy to escape Io's weak gravity.

The glow question was answered by intensive spectral studies, carried out by Dr. Jay T. Bergstralh, JPL astronomer, Matson and Johnson, using the 24 in. telescope at Table Mountain Observatory in the Angeles Forest near Wrightwood, California. Observations established that scattering of sunlight by the sodium cloud causes the bright glow.

CONCRETE ON THE MOON

[Concluded from page 93

Conclusions

Concrete is a serious contender for use as a major structural material on the Moon. Much work must be done to define the behaviour and construction of the proposed concrete under lunar conditions, but it is to be hoped that the potential will be exploited to the full. In passing it should be pointed out that a cement such as epoxy resin could be used to assemble garbage into useful material on the Moon or in orbit. 'Scrapcrete' of this type would be good enough for shielding and internal structure, and it would provide a good example of building for the future on the foundations – literally – of the past.

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Spaceflight

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Correspondence and manuscripts intended for publication should be addressed to the Editor at 12, Bessborough Gardens, London, SW1V 2JJ.

Members who would like to present papers to General Meetings, Main Meetings, or contribute to Space Study Meetings, are invited to write to the Executive Secretary, British Interplanetary Society, 12, Bessborough Gardens, London, SW1V 2JJ.

Symposium
Theme **STARSHIP STUDY REPORT**
To be held in the Tudor Room, Caxton Hall, Caxton Street, London, S.W.1. on **26 February 1975**, 6.30-8.00 p.m.

Reports will be presented on various aspects of the Starship Study by members of the Daedalus team.

Admission tickets are not required. Members may introduce guests.

Film Show
A Programme of New Films on the theme of **SKYLAB** will be held in the Botany Lecture Theatre, University College, Gower Street, London, W.C.1. on **11 March 1975**, 6.30-8.30 p.m.

The Programme will be as follows:-
(a) Skylab: The Search & The Hope
(b) Skylab: Mission Made Possible
(c) Skylab: The Second Journey
(d) Spaceship Skylab: Wings of Discovery

Admission tickets are not required. Members may introduce guests.

Space Study Meeting
Theme **THE VIKING PROGRAMME** by P. J. Parker.
To be held in the Kent Room, Caxton Hall, Caxton Street, London, S.W.1. on **4 April 1975**, 6.30-8.30 p.m.

Admission tickets are not required. Members may introduce guests.

Main Meeting
Theme **EUROPEAN PARTICIPATION IN EARTH RESOURCES (SPACE) PROJECTS**
(To consider National, ESRO/ESA activities in relation to ERTS-1, Skylark, Skylab, ERTS-B, etc.).
To be held in the Large Physics Lecture Theatre, University College, Gower Street, London, W.C.1. on **9 April 1975** *(All day).*

Papers offered to date are as follows:-
1. Potential Applications of Space Image Analyses and the Development of Natural Resources, by Dr. D. Bannert
2. Coordination of Remote Sensing Objectives, by S. R. Dauncey
3. Comparison of the Utility of Alternative Camera, Film & Filter combinations for Space Photography from the Skylark Earth Resources Rocket, by Dr. J. R. Hardy
4. Attitude Control of Earth Resources Rockets by an RF Interferometric Sensor, by Dr. G. Mayer
5. Application of ERTS-1 Imagery to the Sudan Savanna Project, by C. W. Mitchell
6. Automation of Earth Resources Data Analysis, by O. E. Morgan
7. Use of Photographic Imagery for Earth Resources Studies, by Dr. E. S. Owen-Jones
8. Recent results from the use of ERTS, Skylab and other remote sensed imagery in mineral exploration, and their significance in planning future Earth Observation Projects, by N. Press
9. Telespazio Facilities for Acquisition & Processing of ERTS Data, by Ing. B. Ratti
10. The Use of ERTS Imagery, by L. P. White

Offers of further papers are invited. Further details are available from the Executive Secretary.

Space Study Meeting
Theme **SATELLITE TRACKING** by Dr. D. G. King-Hele.
To be held in the Kent Room, Caxton Hall, Caxton Street, London, S.W.1. on **17 April 1975**, 6.30-8.00 p.m.

A general review of the radio and optical methods used in satellite tracking, their effectiveness and some of the results achieved.

Admission tickets are not required. Members may introduce guests.

Space Study Meeting
Title **A DEVELOPMENT STRATEGY FOR A EUROPEAN MINI-SHUTTLE** by D. Ashford.
To be held in the Kent Room, Caxton Hall, Caxton Street, London, S.W.1. on **6 May 1975**, 6.30-8.00 p.m.

Admission tickets are not required. Members may introduce guests.

26th IAF CONGRESS
To be held in Lisbon (Portugal), from **21-27 September 1975.**
The theme will be 'Space & Energy'.

Main Meeting
Theme **COMPUTER TECHNIQUES IN SPACE PROJECTS**
To be held in the Large Physics Theatre, University College, Gower Place, London, W.C.1. on **24 September 1975** *(All day).*

Offers of papers are invited. Further details are available from the Executive Secretary.

Main Meeting
Theme **AERONAUTICAL AND MARITIME SATELLITES**
To be held in the Large Physics Theatre, University College, Gower Place, London, W.C.1. on **25 September 1975** *(All day).*

Offers of papers are invited. Further details are available from the Executive Secretary.

Short Film Evening
A Programme of short (10-15 min.) films not previously screened by the Society will take place in the Botany Lecture Theatre, University College, Gower Street, London, W.C.1. on **29 October 1975**, 6.30-8.30 p.m.

Admission tickets are not required. Members may introduce guests.

Lecture
Title **DIRECT SPACE PROBE INVESTIGATIONS OF COMETS** by Dr. D. W. Hughes.
To be held in the Lecture Theatre, Royal Society of Arts, John Adam Street, Strand, London, W.C.2. on **7 November 1975**, 6.30-8.30 p.m.

Admission tickets are not required. Members may introduce guests.

Repeat Film Show
A Programme of some of the most popular films which have been featured over the past two years, will be held in the Botany Lecture Theatre, University College, Gower Street, London, W.C.1. on **3 December 1975**, 6.30-8.30 p.m.

Admission tickets are not required. Members may introduce guests.

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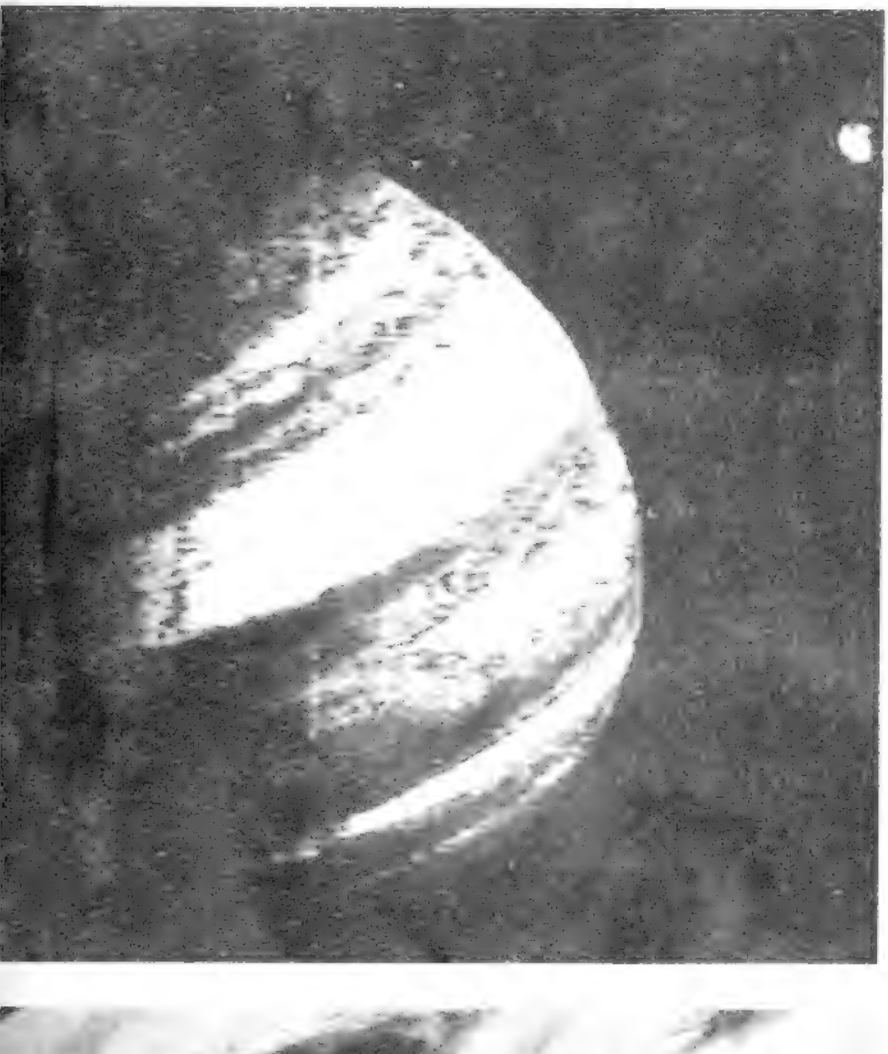

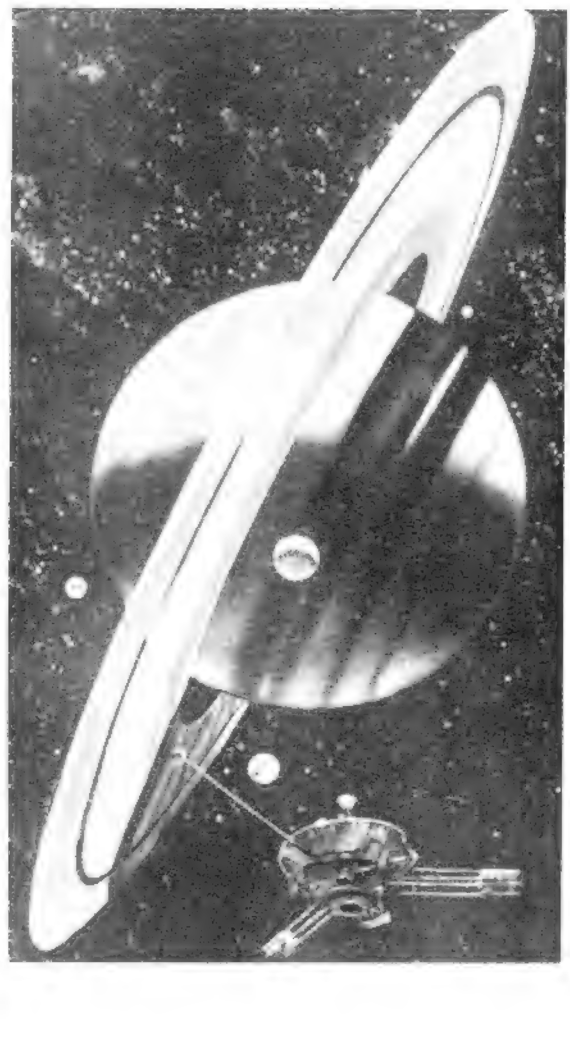

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COVER

PIONEER 11 WILL FLY PAST Saturn in early September 1979. The 568 lb. spacecraft, originally targeted to Jupiter, began the "bonus" portion of its interplanetary flight after it had passed 26,725 miles above Jupiter's clouds on 2 December 1974. Accelerated to more than 100,000 m.p.h. by Jupiter's gravity in a 'sling-shot' manoeuvre, Pioneer 11 then started its 2,000 million-mile-plus trip to Saturn. According to present plans, the spacecraft will fly between the inner ring of Saturn and the planet's visible surface; it will then proceed outbound for a close look at the Saturn moon Titan eventually to leave the Solar System. *Top left,* Pioneer 11 image of Jupiter and the third Galilean satellite Ganymede; *Bottom,* artist's impression of Pioneer over Jupiter's Red Spot; *right,* during Saturn encounter in 1979.

National Aeronautics and Space Administration

SPACEFLIGHT

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MILESTONES

January

13 By noon (Moscow time) Salyut 4 has made 288 revolutions of the Earth, including 18 with cosmonauts on board. Orbit is 342-355 km x 51.6 deg x 91.3 min. Higher orbit in which station operates halves the consumption of manoeuvre fuel in comparison with earlier vehicles.

14 NASA re-names the Earth Resources Technology Satellites (ERTS) – "Landsat".

19 *Novosti* reports that Salyut 4/Soyuz 17 combination continues to orbit the Earth – at 335-340 km. Station incorporates a Filin X-ray telescope and X-ray counters for locating pulsars and neutron stars, a 25 cm (9.8 in.) solar telescope and various biological experiments. All systems functioning normally.

22 NASA launches Landsat 2 – the second Earth Resources Technology Satellite – by Delta rocket from Western Test Range, California, at 17.56 GMT. Near-polar orbit is almost circular at 570 miles (917 km) altitude.

22 Last major meeting of Apollo-Soyuz Test Project (ASTP) working groups in the United States prior to July mission gets underway at Johnson Space Center, Houston, Texas. Soviet party totals some 80 Soviet aerospace specialists and officials.

24 Salyut 3, launched 24 June 1974, re-enters atmosphere over Western Pacific on command from Soviet Mission Control.

February

3 Salyut 4/Soyuz 17 combination exceeds Soviet duration record for manned space flight of 23 days 18 hours 22 minutes set by ill-fated Salyut 3/Soyuz 11 crew in June 1971.

6 France launches 103.6 lb. (47 kg) Starlette satellite by first Diamant BP.4 rocket from Kourou, French Guiana, to achieve orbit of 500-707 miles (805-1,138 km) altitude inclined at 49.83 deg to equator. Experiment to measure with great precision the shape of the Earth and gravitational anomolies.

7 Radio tracking group at Kettering, England, picks up voice reports from Salyut 4/Soyuz 17 indicating that cosmonauts are preparing to return. Mission becomes third longest manned space flight, exceeding 28 days set by first Skylab boarding party in 1974.

8 Salyut 4 completes 700 Earth-revolutions, 430 with a crew on board. Orbit: 334-361 km x 51.6 deg x 91.3 min.

8 Soviet cosmonauts make first visit to Kennedy Space Center. Party includes Lt-Col. Alexei Leonov and Valeriy Kubasov, prime crew for Soyuz ASTP mission and their reserves; Vladimir Shatalov, head of the cosmonaut office, and Valeriy Bykovsky, training director. Three-days visit to Florida space coast includes: Tour of KSC on 8 February; visit to Disneyland, Orlando, on 9 February and inspection of Saturn IB rocket and Apollo CSM at KSC on 10 February. Party then proceeds to Texas for three weeks of training at Johnson Space Center. (U.S. ASTP astronauts to make exchange visit to Tyuratam cosmodrome in Central Asia to inspect Soyuz in May).

[Continued on page 128

ESCAPING THE LIMITS TO GROWTH

By Michael A. G. Michaud

The Human Dilemma

Sludge creeps across the ocean floor toward the pleasant beaches of Long Island. Where did it come from? From men dumping the waste products of industrial civilization into the waters off New York City.

A brutal drought destroys the rural economy of Sahelian Africa and leaves its people in danger, dependent on airlifted food. How did it happen? An expanding population pushed too far into marginal lands, and their numbers and their abandonment of time-tested methods made their fragile ecosystem vulnerable to a slight shift in wind and rain patterns.

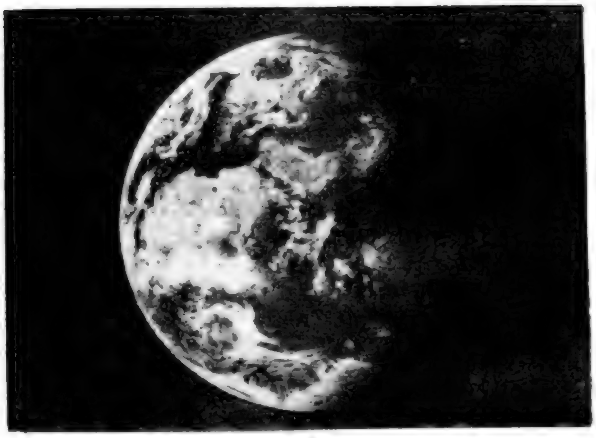
In storage containers scattered throughout the world, radioactive waste products accumulate quietly. Some will still be dangerous thousands of years from now, placing an impossible burden on the systems that are meant to seal them off from the environment. Why? Because of humanity's growing demand for energy to power its factories and its conveniences, and because of its appetite for more destructive weapons.

We see the warning signs all around us: humans have developed an unprecedented power to make themselves an endangered species. We have been sensitized to runaway population growth, the poisoning of the oceans and the atmosphere, growing pressure on the easily accessible natural resources on which the present world economy depends, shortages of food and goods caused by expanding numbers and purchasing power, the continuing threat of nuclear war, and an apparently general inability to manage the effects of technology and anticipate related social change. We have become conscious that our biosphere is, in many ways, a closed system; damage to one part of the system reverberates through the rest. We have been reminded that the human species is interdependent, and that its political subdivisions may hamper its survival more than they help it. And, more than ever before in history, we have realised that our future is threatened, not by nature or the supernatural, but by human activity.

An End to Growth?

Much of the current debate on these issues revolves around the concept of the limits to growth. Some projections of current trends, such as those done by J. W. Forrester in *World Dynamics* and Dennis Meadows and his team in *The Limits to Growth,* indicate that humanity will face a "crunch" within the next century due to the combined effects of population growth, pollution, shortages of food, natural resources, and energy, and a deterioration in the quality of life. According to this school of thought, economic growth based on industrialisation and expanding markets cannot continue indefinitely; sooner or later, we must evolve into a steady-state system that recycles its resources and is in balance with its environment.

Critics of this theory argue that its assumptions are wrong, and that it seriously underestimates the human ability to change, adapt, and invent. We have barely scratched many of Earth's resources, and we can find substitutes for those that are easily exhausted; new technologies and new ways of organising human activity can postpone the crash for centuries, if not indefinitely. Others argue that limiting growth is profoundly inequitable, since it could preserve the dominant, privileged position of wealthy societies and deny most of the human species an opportunity for equal status. And Ronald Ridker has written in *Science* that the relevant question is not whether to grow or not grow, but how to redirect economic output so that it will better serve humanity's needs.



"The fragile miracle of life; spinning blue in the sea of black; precious beyond compare; sacred in its wondrous possibility."

Dean Francis B. Sayre, Jr., on the occasion of the dedication of a 'space window' at the Washington Cathedral in which is preserved a rock from the Moon.

Clearly, there is some merit in the arguments of both sides. The Earth and its biosphere are finite, but we can adapt and change to prolong the life of our resources and minimize our impact on our environment. Present shortages result more from rapidly rising demand, commercial calculations, and short-sighted policies than from the exhaustion of resources; however, any single resource on which we place significant demands eventually will be beyond the reach of economically and technologically feasible recovery. A new ethic, more emphasis on recycling, and better planning will help to postpone a resources crisis, but perhaps not indefinitely.

The less developed countries have a right to a better standard of living, but their industrialisation and increased consumption will place serious new strains on world resources and the biosphere (Arthur Clarke once said that the end of the world will come when every Chinese owns a motorcar).

How do we redistribute wealth and resources more equitably to meet the rising demands of the Third World? That will require a new world political and legal system, whose outlines we can perceive dimly at best, but whose foundation is being laid through such international meetings as the world population conference and the conferences on the law of the sea. Some redistribution of power in the world seems inevitable, and may have begun with the escalation of oil prices in the last few years.

In the long run, there are limits to what we now call growth. Even if the exhaustion of resources were not a problem, human society on Earth must remain within limits imposed by the flow of energy into the biosphere (most of this energy ultimately comes from the Sun), the heat balance, and entropy – the running down of the energy within any system.

We will have to adjust long before we reach those ultimate limits. But the real cost may be not so much material as psychological; imposing limits on human enterprise would exact a price from the human spirit, and could cause our descendants to suffer from mental claustrophobia. As Robert Heilbroner suggested in *An Inquiry into the Human Prospect*, the solutions to our problems could be very costly in terms of freedom, intellectual curiosity, and scientific progress. We might achieve a steady-state society, but the likely price would be a loss of social mobility, a caste system, and intellectual fossilization. The ensuing stagnation would reduce our ability to solve the new problems that inevitably will appear. And we might end it all suddenly in a total war with nuclear, chemical, and biological weapons.

At least one factor has been left out of this gloomy picture. The human ecosphere is no longer closed. Within our lifetimes, we have begun to open an option to life within Earth's endangered biosphere, a safety valve for an increasingly crowded, overburdened Earth, a way for humans and the human spirit to escape the ultimate limits to growth on this planet. That escape route is space flight.

The Role of Space

No one seriously argues that space flight could, in the foreseeable future, carry enough of the human species to new biospheres to solve our problems here on Earth. Nor would any serious person say that we should give spaceflight higher priority than solving immediate human problems. But spaceflight gives us tools to help solve these problems, and will open up new resources for future generations. And we would be foolish indeed to give up the option of interplanetary and interstellar flight while we deal with those problems, because that could mean throwing away the means of survival for our species in some future crisis, or postponing that means until it is too late to help us.

Let us be clear about the real purposes of space flight. The point is not technological success, or national prestige. It is to accomplish human purposes that benefit all of us. Space flight in the near Earth sense, which we have achieved already, gives us an unprecedented ability to monitor the biosphere and human economic activity. The machines we put into orbit, and the manned stations that will follow them, are and will be crucial weapons in the fight against hunger and pollution. They will allow us to control aviation, shipping, and land use more intelligently and efficiently. Already, they have begun to locate important new mineral resources, and to identify new prospects for fishing, agriculture, and forestry. They give us advance warning of plant disease. Reconnaissance satellites reduce the fears nuclear powers have of one another and make strategic arms limitations possible. Communications satellites have been a major factor in creating a world consciousness and a sense of human interdependency. The overall effect of orbiting space systems will be to encourage human unity, and to help us prevent the crunch from ever happening.

Space stations will offer new solutions for pollution, industrial blight, a disturbed global heat balance, and scarcities of energy and minerals. G. Harry Stine has pointed out that the Space Shuttle makes possible a Third Industrial Revolution, allowing us to place some of our factories in orbit, where their discharged heat and waste products would not disturb the biosphere. Space systems would have easy, unfiltered access to the greatest source of energy in the Solar System: the Sun. Mineral resources from the Moon and the asteroids can be transferred to Earth orbit at a lower cost in energy than similar raw materials from the Earth, and the Moon itself is a potential location for industry. Space systems could allow us to solve the expanding and frightening problem of radioactive wastes from nuclear power plants by firing them into the Sun.

These near term benefits of spaceflight are impressive enough, but we must look beyond them to the most profound human purpose of space flight: to expand the realm of Man, giving the species new options for survival, evolution, and growth – both in quantity and quality. On Earth, we are creating the potential for the destruction or crippling of our species. By opening a window to the stars, we can assure that at least some humans – and human culture – will survive no matter what happens on the Earth. We can assure that humans will not be limited in the end by the unwise use of the planet which evolved them, by the authoritarian society which ended that abuse, or by conflicts among themselves.

Critics of this idea argue that it is too remote to be "relevant". Yet, only 12 years after Yuri Gagarin began the history of manned space flight, we were able to maintain humans in orbit for months at a time in Skylab. The 1980's will see permanent manned space stations, and the decade after that may see permanent habitation on the Moon. Given a continuing, long-term effort – not an Apollo-type crash programme – it is only a matter of time before we can colonise the most habitable of the planets, and begin to look for new homes among the stars. We are not far from a "lifeboat" capability for those most advanced products of Earth's biological evolution – ourselves. And let us remember that even the most pessimistic of the Limits to Growth school do not foresee the "crunch" coming until the middle of the next century.

Social Space Programmes

Many would say that the cost of a space programme is too high, and that the money should be spent on "social programmes". That is an artificial distinction; an intelligently directed space programme *is* a social programme, since it is the extension of human activity into a new dimension, for human purposes. The cost is tiny compared to human spending on weapons, or even on liquor and cigarettes. And the money is not spent in space, but on Earth, on human services and human enterprises, and human employment. The cost *per capita* can be reduced substantially by making interplanetary and interstellar exploration an international enterprise, avoiding the duplication of competing national programmes; the agreement between NASA and a European consortium for the building of Spacelab is an important step in this direction. To say that it is a waste to develop space vehicles for human purposes is equivalent to saying that we never should have built ships to cross the oceans, or trains, or highways. A space programme is a means, not an end.

Basically, human problems must be solved on Earth. But we must face up to the possibility that we might fail. Is it better to be fatalistic – even masochistic – and say that disaster is our just reward? Or is it better to sieze on this completely new dimension of potential human existence, and escape the limits of growth on Earth? We are not wise enough to design that ideal, self-maintaining, steady-state system that some advocates of the limits to growth appear to visualise. So let us be wise, and take out an insurance policy for the uncertain future. And let us expand our ecological niche, and open infinity to the human spirit.

THE RESOURCES OF THE SOLAR SYSTEM

By Dr. R. C. Parkinson

Introduction

The landscapes of science fiction have receded as our spacecraft have crossed the Solar System. Mars with its canals and ancient civilizations, and the steamy swamp jungles of Venus have proved equally illusory. The Solar System has proved a less hospitable place than we dreamed. Under such circumstances can we still expect to see the colonization of the planets, or will we simply send exploratory, scientific missions to learn what they can and then return?

In an earlier article [1] it was argued that there were economic reasons in favour of using a Lunar Colony to supply raw materials for spaceborne manufacturing industries. Once established, such a base might prove attractive for other reasons – particularly if transport costs can be kept low – and the development of Earth-Moon space appears quite probable.

With the establishment of such a Colony we can begin to see reasons for considering the exploitation of the resources of the rest of the Solar System. As with the Lunar Colony, the aim would not be to supply raw materials to the Earth (something which is unlikely ever to be profitable in the foreseeable future), but to provide resources for spaceborne industries and the growing Lunar Colony for less cost than would be required in ferrying materials up from the Earth. The first criterion for the successful exploitation of extraterrestrial resources is simple – it must be possible to deliver a greater mass of useful material to orbit round the Earth, or to the Moon's surface, than was assembled in Earth orbit in the first instance to begin the operation, and it must be possible to do this in a reasonably short period of time.

Accessibility

The first problem is one of access. The Earth lies at the bottom of a deep "gravitational well". To place an object in orbit about the Earth requires a velocity change of about 7700 m/sec. If we were to give that object an equal further velocity increase we could place it beyond the orbit of Jupiter. Table 1 shows a number of velocity requirements for access to places which might be of interest, both from a close orbit about Earth, and for an orbit about the Moon.

But accessibility is also a question of the sort of propulsion system that we can use. For transport into Earth orbit, the Space Shuttle uses high pressure lox-hydrogen engines with a vacuum specific impulse of about 4500 m/sec*. In space we can use higher performance nuclear engines, such as the solid core NERVA [2] with a specific impulse of about 8000 m/sec. But the *exploitation* of the Solar System will require even higher engine performances – nuclear-electric, gas core nuclear, or thermonuclear engines. The high performances of any nuclear propulsion system, however, will be achievable only in space. Problems of shielding, radioactive contamination, and poor thrust-to-mass ratio make it appear that chemical rockets will always be required for descent to and ascent from planetary surfaces.

Gas Core Nuclear Propulsion

Let us briefly consider just one of the possible advanced nuclear propulsion systems which might be used for the exploitation of the Solar System. Thermonuclear propulsion prospects have been surveyed fairly recently in *Spaceflight* [3], and ion motor propulsion systems are fairly familiar, but it may be relevant to make some comments on the prospects for gas core nuclear propulsion.

The limit on the performance of a conventional nuclear rocket such as NERVA is the temperature to which the solid core components can be raised before melting or structural failure occurs. In a gas core reactor much higher gas temperatures can be achieved by producing the nuclear reaction within a uranium plasma confined as a "fireball" within a cooling flow of hydrogen Fig. 1. The central "fireball", it is proposed, might attain temperatures of 22,000°K. The radiant energy emitted by this "fireball" would be absorbed into the surrounding hydrogen by "seeding" the gas with very small opaque particles. The main difficulty would be in keeping the solid parts of the engine cool, and ultimately limitations on the amount of heat filtering through to the walls would limit the performance of the gas core nuclear rocket. Even so, specific impulse values of 30-50,000 m/sec appear feasible.

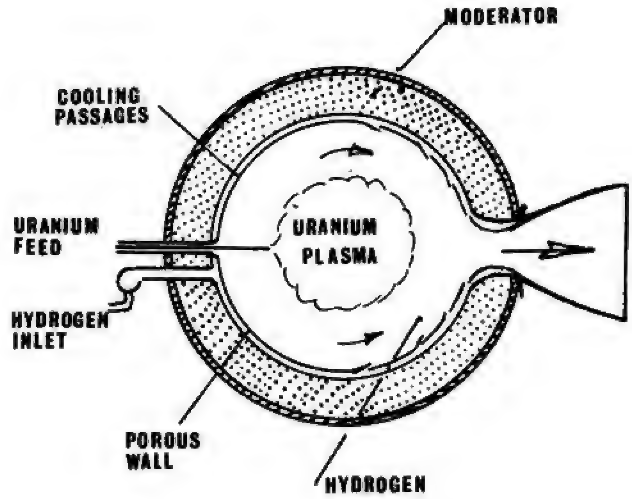


Fig. 1. Gas core nuclear reactor – a "fireball" of fissioning uranium plasma is maintained within a stagnant cavity surrounded by a cooling boundary layer of hydrogen propellent. Exhaust velocities in the region of 35,000 m/sec might be achieved from this engine.

Ragsdale [4], reporting in 1972 on the status of the gas core nuclear rocket, concluded that nuclear criticality was achievable within a large, stable cavity that would permit loss rates of the nuclear material to be kept as low as one part in 200-350 of the propellent flow, that the cavity walls could be thermally protected by seeding the hydrogen with small particles, and that ground testing of a reactor should be possible. The engine mass would lie in the range of 50-250,000 kg.

Venus and Mars

The nearest planets to the Earth are Venus and Mars, both in terms of distance and the velocity change required to transport vehicles from Earth orbit to these destinations. Using gas core nuclear propulsion very high ratios of payload transferred to propellent required can be achieved. Assuming a propulsive specific impulse of 35,000 m/sec, 12 times the initial propellent mass could be transferred one way from Mars orbit (with a two way vehicle), or 1.75 times the propellent mass could be transferred each way, with a 25% vehicle inerts mass fraction. For Venus the equivalent figures are 9.7 times for one way transfer, and 1.37 for a two-way transfer. This means that if material were available in orbit about either planet which was not readily available in near-

Table 1

	Total delta-V requirement (m/sec)	
	From 1000 km Earth Orbit	To close orbit about the Moon
Earth orbit to the Moon		3890
Minimum Venus capture	5260	4110
Close orbit about Venus	6670	5530
Close orbit about Mars	5580	4380
Rendezvous with Ceres	9750	10430
Aphelion rendezvous with Comet Encke	11100	12440
Minimum Jupiter Capture	10260	11890
Close orbit about Callisto	11580	13210

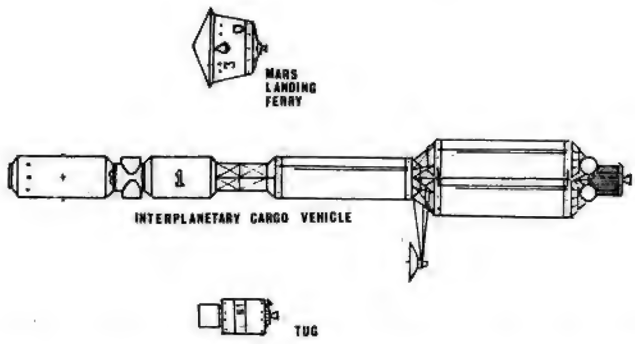


Fig. 2. A re-usable Mars landing ferry, using atmospheric braking and liquid oxygen extracted from surface rocks for propellent for the ascent could deliver more payload into orbit round Mars than propellent required to be brought from the Earth. A nuclear interplanetary cargo vehicle would deliver cargo back to the Earth. Mars is a possible extraterrestrial resource.

Earth space or on the Moon, it would be economic to ship propellent up from the Earth for the purpose of bringing the cargo home.

The only material available "in orbit" about either planet would be the upper atmosphere, which might be "mined" by a PROFAC vehicle [5] dipping into the upper layers and collecting the gases. Unfortunately, the atmosphere of neither planet appears particularly interesting from the present limited commercial viewpoint. The Venusian atmosphere consists almost entirely of carbon dioxide, the oxygen component of which is much more readily collected by a PROFAC vehicle about Earth, or by extraction from the lunar rocks. Mars has a thinner atmosphere, again without attractive components.

In the case of Venus, there is some suggestion that more interesting compounds may exist at lower altitudes, that the lower clouds could contain mercury compounds [6]. A vehicle designed to collect these materials, however, would need to slow to low velocities by atmospheric braking, and then at the end of its mission accelerate back to orbital velocities.

The condition for a vehicle to deliver into orbit more mass than required in propellent is

$$\frac{v}{c} < \ln\left[\frac{2}{1+k}\right]$$

where v is the velocity requirement, c the specific impulse, and k the vehicle inert mass fraction. For Venus this would involve specific impulse values in the range 14-17,000 m/sec, which are impossibly high for any system which we might think of using within the Venusian atmosphere. Some attention has been given to possible ramjet systems which could be used for cruise purposes, burning in the Venusian atmosphere [7] and these might ease the problem slightly, or if liquid oxygen could be produced "on site" (most probably by an orbiting collector rather than a ground based station) then the performance might be improved in terms of the propellent which must be brought from Earth sufficiently to make an economic orbital ferry marginally possible. But even at its best we can only imagine such a system as barely possible, and the rewards needed to make it attractive would have to be very great indeed.

Mars, besides having somewhat less hostile surface conditions, is also an easier proposition. The minimum specific impulse requirement is 7-8,000 m/sec, and if liquid oxygen could be produced locally, a lox-hydrogen fuelled shuttle would be quite attractive Fig. 2.

It is not obvious just what resources might be available on Mars which might not more easily be obtained on the Moon, and which would be considered worth shipping back, but this may be the product of our present ignorance. At the moment Mars represents a *possible* point for colonization.

Comets and Asteroids

Beyond Mars lie the Asteroids and the aphelions of the short period comets (represented in Table 1 by Ceres and Encke). Both comets and asteroids are attractive in that they have negligible gravitation, so that rather than having to supply a landing vehicle we could cruise right up to the surface using nuclear propulsion. On the other hand, the low gravity also means that we cannot use "gravity assist" manoeuvres in the rendezvous, so that the velocity requirements tend to be high.

Concerning resources, comets have the attraction of having large quantities of hydrocarbon and hydrogen-containing ices associated with their nucleus, and hydrogen (or water) is one very important substance which appears to be in short supply on the Moon. Asteroid missions may provide access to high grade nickel-iron ores if meteoric data is representative, but the object is to provide material which cannot be obtained from the Moon and it is not apparent that nickel-iron ore fits this criterion. Cometary material also is probably not the best source of hydrogen and hydrocarbons for

* *Specific impulse is the thrust of a rocket produced by unit mass flow of propellent, and in metric units is measured in Newtons per kilogramme per second which has the same units as, and is approximately the same as, the rocket exhaust velocity when we operate in vacuo.*

near-Earth space. The velocity requirements are greater than for missions to the Jupiter system, and since rendezvous must be made at aphelion opportunities are few and far between.

Ironically, then, although comets and asteroids approach the Earth-Moon system more closely than any other interplanetary body, their resources are actually less accessible and less attractive than more distant targets.

Jupiter System

Jupiter dominates the Solar System. In both volume and mass it is larger than all of the other planets put together. Its atmosphere contains all the hydrogen that Mankind could ever need. And it is circled by satellites in a miniature Solar System. The velocity requirements for travel between the inner satellites are high – as high as the requirement for getting from Earth to Jupiter in the first place – but transfer times are low, and there is good reason to think that ice and other frozen gases containing hydrogen are to be found on the surfaces of the major satellites in abundance. Until *Pioneer 10* made its historic run through the system there was good reason to suppose that Jupiter could provide a major area for colonization.

Pioneer 10 showed once again that the reality was less hospitable than our dreams. The trapped radiation belts about Jupiter provide a lethally high radiation environment for all the inner satellites except Callisto [8].

Fortunately Callisto appears to be a good target in itself. There is a good chance that we shall be able to find hydrogen containing ices on Callisto [9], and in addition the radius at which Callisto circles Jupiter is very close to the optimum radius which we would choose if we were to make maximum use of "gravity assist" from the vast pull of Jupiter to minimise our velocity requirements.

To generate hydrogen by electrolysis from water requires about 39 kW-hr/kg of hydrogen produced. If we were to place an electrolysis plant on Callisto, together with equipment for liquefying the hydrogen, and add to this power requirement something for propellent for a ferry or "lighter" vehicle to place filled tanks in orbit about Callisto ($\Delta V \sim$ 1040 m/sec), then a total power requirement of about 50 kW-hr/kg of hydrogen delivered into orbit would be sufficient to provide as much hydrogen as was needed. A 2 MW station could produce about 350 tonnes of liquid hydrogen per year.

By contrast, if we were to use a PROFAC vehicle to scoop hydrogen from the upper levels of Jupiter's atmosphere the power requirement would be about 140 kW-hr/kg in an equivalent orbit, a production rate of perhaps one quarter of the Callisto plant.

Now let us look at the economics of bringing this hydrogen back to the Earth-Moon system.

Economics of Callistan Hydrogen

As has already been stated, the requirements for an economically exploitable resource is that it must provide something which is not available in space in the Earth-Moon system, that it must provide more of it than the mass originally required to be assembled in Earth orbit at the outset of the expedition, and that it must be done within a reasonably short time (the break-even time). Hydrogen fulfils the first criterion. The other two are dependent upon the vehicle performance.

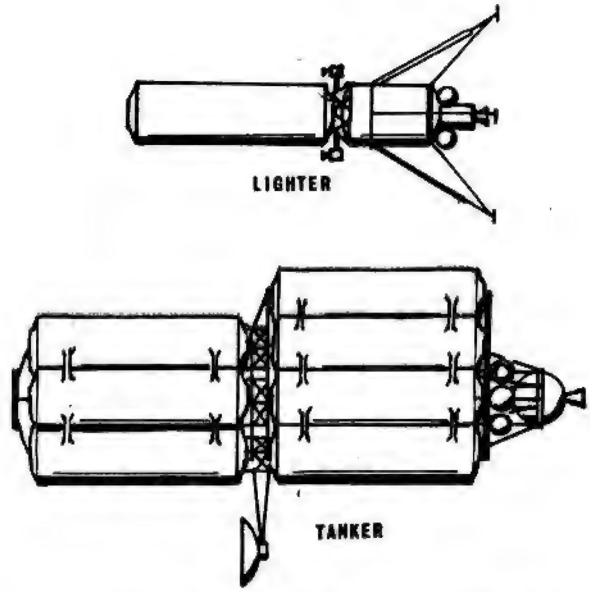


Fig. 3. A lighter would deliver filled liquid hydrogen tanks from the surface of Callisto to a gas core nuclear powered tanker in orbit about Jupiter – in reality a collection of liquid hydrogen tanks. Liquid hydrogen from the Jupiter system could be competitive in Earth-Moon space with hydrogen brought up from the Earth.

We may presume that the expedition which must initially be assembled to recover hydrogen from the Jupiter system will consist of three parts – a large tanker vehicle capable of transporting hydrogen back from the Jupiter system and which will act as a ferry for the expedition to Callisto in the first place, an electrolysis plant capable of generating liquid hydrogen on Callisto, and a "lighter" capable of operating between the surface of Callisto and orbit. The tanker vehicle will be assembled from a collection of identical tanks (possibly with a filled mass in the vicinity of 25,000 kg since this represents the Space Shuttle cargo capacity) and powered by a gas core nuclear reactor Fig. 3. The lighter will be a chemically propelled vehicle capable of landing one empty modular tank on Callisto, and returning with a filled tank into orbit. Having acquired a full load of hydrogen, the tanker will then return to the Earth, using some of the hydrogen as propellent along the way, and reserving a small amount more for later return to the Jupiter system.

In practice it seems probable that a number of tanker and lighter vehicles would be involved, but the basic concept can be studied round this simple outline. If n is the ratio of the round-trip time to the break-even time, then for economic operation the mass fraction of the expedition devoted to the lighter and electrolysis plant (in terms of the fully loaded tanker mass, *not* the original expedition mass) M_m is given by

$$M_m < \frac{1}{n} e^{-2v/c} - M_i \left(1 + \frac{1}{n}\right)$$

where M_i is the inerts mass fraction of the fully loaded tanker, v is the one-way total velocity requirement, and c the specific impulse. If we suppose $M_i = .25$, c = 35,000 m/sec, and n = .7, we find that (using the most economic orbit), the mass fraction devoted to lighter and plant must be less than

0.13 of the fully loaded tanker mass. In terms of the large vehicles envisaged for gas core nuclear propulsion this is not unreasonable. The tanker would deliver 0.37 of its total mass as hydrogen on each trip, and the original mass of the expedition assembled in Earth-orbit would be only 0.529 of the maximum tanker mass (i.e., it would go out for the first time half empty). The cycle time must be an integral number of synodic periods (that is, the time between successive oppositions of the Earth and Jupiter), and for this minimum energy transfer the cycle time is 5.46 years. The break-even time for the system to deliver more hydrogen to the Earth-Moon system than was originally orbited about Earth would be just 7.8 years.

If we are prepared to consider higher energy, faster orbits between the Earth and Jupiter, then it may be possible to improve on these figures. The velocity change requirements rise, but the pay-off time can be reduced. The pay-off may not be as spectacular as – for example – lunar mining, but because nuclear propulsion can be used for nearly all of the transfer operation it may indeed be more economical to ship hydrogen all the way from Callisto to Earth orbit than to lift it a few hundred miles from the Earth's surface! Supertankers of liquid hydrogen may someday cross the Solar System as today supertankers of oil ply Earth's oceans.

Jupiter Mining

What of the giant planet itself? Is there a possibility that one day we may descend into the atmosphere of that vast planet in search of new resources.

Not perhaps with manned expeditions. Even if it were possible to shield manned craft for the descent through the Jovian van Allen belts, operating at two and one half Earth gravities is not an attractive proposition. However, robot vehicles may be expected to become more sophisticated, and it is just possible that someday we may become interested in Jupiter itself. The high pressure, hydrogen rich atmosphere containing other hydrocarbon and ammonia based compounds may prove to have a very exotic chemistry. The high escape velocity of the planet (60 km/sec) means that descents into that atmosphere will always be costly, but we may find substances which will justify that cost.

Indeed, Jupiter may be less awesome an enterprise than first sight may lead one to presume. The big jump is to achieve close orbit about the planet ($v = 42$ km/sec), and three factors help us – the spin of the planet, the temperature, and the composition of the upper atmosphere.

Jupiter turns on its axis in 9 hours and 55 minutes. This means that the equator has a rotational velocity of 12.6 km/sec – more than one quarter of the orbital velocity!

Then, the hydrogen atmosphere makes a good propellent. It can even be used as ramjet propellent, and the upper speed limit of a ramjet is a function of Mach number, which is helped by the fact that the speed of sound in the Jovian atmosphere is probably about three times that of the Earth (because of the low molecular weight). And in addition, because the hydrogen is cold, a ramjet can be operated at higher Mach numbers before compression temperature effects limit performance. The net result is that we might fly a ramjet in the upper Jovian atmosphere at speeds of up to 10 km/sec. Couple that with the rotational velocity and we are over halfway to achieving orbital velocity.

There is one possible cargo which we might consider, even now, taking from the Jupiter atmosphere. That substance is the rare helium isotope, helium-3. The BIS *Daedalus* starship

Fig. 4. Mars Shuttle craft.

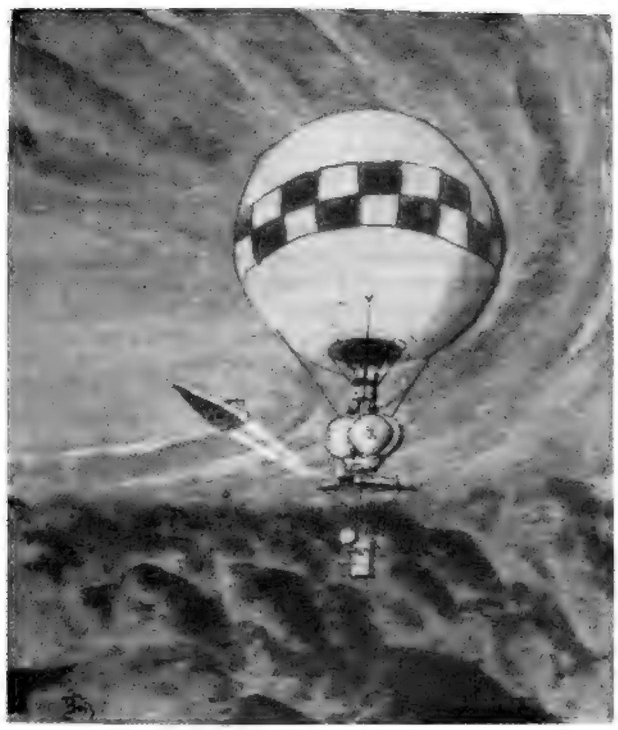


Fig. 5. A Jupiter Aerosat: valuable chemicals within the Jupiter atmosphere may one day be "mined" by hot air balloons floating in the atmosphere, and served by nuclear powered rockets using the Jovian atmosphere for propellent.

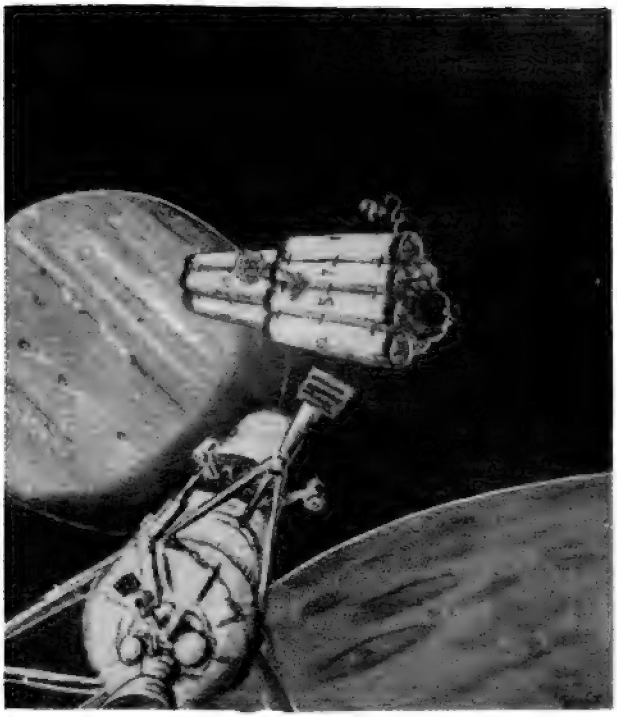


Fig. 6. Tanker rendezvous above Callisto.

study [10] has suggested that deuterium/helium-3 pulsed-fusion engines might be used to propel an interstellar vehicle (and interplanetary vehicles also, at that). The propellent requirement for an interstellar vehicle would be vast (a figure of 90,000 tonnes of helium-3 has been suggested), and because helium-3 is so rare the original proposal was to use a fusion breeder reactor sited on the Moon to manufacture the isotope. Generating this propellent supply over a 20 year period, such a reactor would require a power of about 5×10^{14} watts! But helium represents about 18% by volume of the Jovian atmosphere. Even allowing for the fact that the isotope that we require is rare, to separate out the same amount of helium-3 and to place it in orbit about Jupiter would require a power of about 300 MW for the same period, of which about 50% is the energy required to lift the cargo into orbit.

Because of the lack of a proper surface to Jupiter, the separation plant would have to be floating within the Jovian atmosphere. The Jupiter station might therefore be in the form of a giant "hot air balloon" carrying the separation equipment and power reactor, and using the waste heat from the reactor to generate the lift. This would be serviced by orbital vehicles capable of using the Jovian atmosphere for propellent. Because it can operate high in the Jovian atmosphere the pressure and temperature environment need not be too excessive, and the size would be dictated only by the vast scale on which the plant would have to operate.

But at this point we have very firmly entered the realms of science fiction. If and when the atmosphere of Jupiter is mined for resources, the colonization of the Solar System will be well advanced.

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ANATOLI BLAGONRAVOV

The distinguished Soviet scientist Academician Anatoli Blagonravov died on 4 February at the age of 80. To the last days of his life he headed the Engineering Research Institute.

Well known to the international space community, Blagonravov played a major role in the development of the Soviet space programme. An obituary over the names of Leonid Brezhnev, Nikolai Podgorny, Alexei Kosygin and Soviet scientists lays stress on his selfless service to the Soviet State, "a combination of high civic duty and fidelity to his calling as a scientist".

For a number of years Blagonravov was deputy USSR representative on the United Nations' Committee for the Peaceful Uses of Space and chairman of the Commission for the Exploration and Use of Space under the USSR Academy of Sciences. He took an active part in the Pugwash movement of scientists for peace and general disarmament.

Academician Blagonravov had been awarded many Orders of the USSR, including the title of Hero of Socialist Labour twice. He was a full member of the Czechoslovak Academy of Sciences and the International Astronautical Academy (IAF).

MILESTONES

Continued from page 121]

9 Soyuz 17 separates from Salyut 4 at 9.08 a.m. (Moscow time); command module soft-lands by parachute under conditions of low cloud and poor visibility, with winds gusting to 65 ft./sec. (20 metres/sec.), at 2.03 p.m. (Moscow time). Cosmonauts Gubarev and Greshko fit and in good spirits after third longest flight in space history lasting nearly 30 days.
Message of congratulation to Soyuz 17 cosmonauts and others concerned with flight, from Leonid Brezhnev, Nikolai Podgorny and Alexei Kosygin, says "establishment of long-functioning orbital stations opens up vast prospects for the exploration of space ... for tackling scientific and economic problems."

MARINER-VENUS-MERCURY 1973 PROJECT HISTORY

By David Baker

PART 1

Introduction

The Mariner series of interplanetary spacecraft have provided a unique opportunity for studying the terrestrial planets spanning the 175 million mile zone between the Sun and the asteroids. Ever since Mariner 2 flew past Venus in 1962 their success has been endorsed by follow-up flights to Mars and a repeat flight to Earth's sister planet. But the planetary programmes of the National Aeronautics and Space Administration have been continually plagued with political indecision, congressional "cold-feet" and a rapidly changing economic climate.

Back in 1962 NASA was confidently predicting an unmanned Mars landing in 1966 with ambitious plans for a soft-landing capsule attached to a Mariner bus. A follow-up flight to the successful Mariner 2 Venus mission was cancelled in 1963, partly to finance this venture. Only Apollo had ready access to inflated funds and little of the additional finances found their way into the coffers of planetary science. Then came cancellation of plans to land a capsule on the Martian surface in 1966, immediately followed by a redirection of emphasis in the assault on the Red Planet. The new schedule anticipated a dual Mars flight in 1969, with soft-landing capsules released during the fly-by, and the landing of an automated biological laboratory in 1971. This latter project, called Voyager, would mount a test flight in 1969 and follow the initial landing in 1971 with additional explorations of the surface in 1973 and 1975.

By the end of 1965 Voyager had been postponed to 1973 and NASA had introduced a new mission – a fly-by of Venus in 1967 using the back-up spacecraft to Mariner 4 which had itself just conducted the first successful fly-by of Mars. Out went plans for sending capsules to the surface on the dual Mariner-Mars 1969 mission and by the end of 1967 NASA was forced to cancel Voyager. Just 12 months later the agency came up with a simplified design called Viking. In January 1970 Viking soft landings were postponed from 1973 to 1975 and a new family was introduced to the stable of planetary robots: Pioneer. In 1972 and 1973 two nearly identical spacecraft set sail for Jupiter and the latter was put on course for a rendezvous with Saturn in 1979.

Before this the so-called Grand Tour of the outer planets was cancelled and replaced with a more economical plan to send two Mariner class vehicles to Saturn by way of Jupiter in 1977. Only Mariner 2 and Mariner 7, both of which flew to Venus, were launched on the mission profile that triggered their conception. All other planetary flights were either modified or cancelled outright to re-emerge under a different guise. Not surprisingly a cautious eye was cast on the project that would ultimately turn out to be the most satisfactory flight launched so far.

First Dual-Planet Mission

Called Mariner-Venus-Mercury 1973 it formally began on 26 February 1970, when a project office was set up at the Jet Propulsion Laboratory. Its primary objective was to make a close inspection of the planet Mercury after flying close to Venus and scanning its cloud shrouded atmosphere with TV cameras and other scientific instruments. It would be the first attempt at interplanetary billiards, a fitting precursor to the Mariners of 1977 and, as it turned out, the Jupiter/Saturn flight of Pioneer 11.

A very detailed examination of the spacecraft, its subsystems, scientific instruments and the flight plan has already been published (*Spaceflight*, 16, pages 25-34, 46-54 and 282-290) and it is not the intention of this paper to repeat that information. Instead, we will follow the project from its inception to launch and record the events which turned this flight into the most rewarding mission of the series.

A field of bright rays, caused by ejecta from a crater radiating to the north from off camera *(lower right)*, is seen in this view of Mercury taken on 21 September 1974 during the second encounter, by Mariner 10. Source of the rays is a large new crater near Mercury's south pole. Mariner was about 30,000 miles (48,000 km) from Mercury when the picture was taken just three minutes after the spacecraft had made its closest approach. Largest crater in this picture is 62 miles (100 km) across.

National Aeronautics and Space Administration

The idea of using the gravitational attraction of Venus to deflect the trajectory of a passing spacecraft to the innermost planet, Mercury, was developed by a UCLA graduate working at the Jet Propalsion Laboratory during summer vacations. In October 1963 the student, Michael A. Minovitch, published JPL Technical Report No. 32-464 in which he presented a detailed analysis of the projected mission under the guidance of Victor C. Clarke. Clarke was later to become Mission Analysis and Engineering Manager for MVM-73. By launching a spacecraft to Venus, he argued, the deflection of hyperbolic velocity resulting from Venus' gravity would cause the heliocentric energy to be transferred from the vehicle to the mass of the planet, lowering perihelion and allowing it to fly close to Mercury if planetary alignment was factored in the calculations. Because of the sensitivity in deflection of the outgoing asymptote a 1 mile miss at Venus would incur a 1,000 mile miss at Mercury on an uncorrected trajectory.

MVM-73 was officially endorsed at the 1968 Planetary Exploration Summer Study by the Space Science Board of the National Academy of Science with a recommendation that only a single spacecraft should be readied for flight. This cost saving move would influence the tight financial control already exhibited by previous Mariner programmes. Immediately, the Goddard Space Flight Center joined JPL in the battle for project management and a Science Steering Group was set up in September 1969. Goddard had long been interested in planetary flight and proposed adoption of an Explorer-class vehicle for the dual-planet mission. However, JPL were advised that the Office of Space Science had selected them for management of a Mariner flight to Venus and Mercury. Costs would be kept to a ceiling of $98 million and this was emphasised in the letter from John E. Naugle, Associate Administrator, OSS, to Dr. Pickering at JPL.

It read: "A major concern has been and remains to be the total runout cost of the project. I am sure you are aware of the cost history for which estimates have ranged from approximately $70 million to well over $100 million. It is mandatory that the project be accomplished for a total cost not exceeding $98 million quoted in your letter and strong efforts should be taken to reduce this figure."

In late February 1970, the initial Programme Authorisation Document was signed and a project office set up at JPL. Briefings with industry were already under way and four aerospace firms submitted proposals for detailed design and manufacture of the Mariner-class vehicle on 28 April 1971. The Boeing Company was selected and a definitive contract signed on 17 June 1971, on a cost plus award fee basis. Boeing had already achieved prominence with Saturn S-IC stages, five Lunar Orbiter spacecraft and three Lunar Roving Vehicles, none of which had failed in their primary objectives. NASA plans for MVM-73 anticipated a launch during the 1 November-15 December 1973, period, leaving less than 30 months to complete and deliver the hardware. Boeing had worked to tight schedules before, witness the LRV programme, and still produced remarkably efficient hardware. Mariner 10, as the vehicle would be called, required 189,540 parts versus the 104,300 of Mariner 9 and the 93,690 of Mariner 6/7. In view of the increased complexity, the short preparation time and the constraints applied on financial outlays Mariner 10 achieved a far higher cost effectiveness/failure report ratio than displayed hitherto.

The personnel who directed the MVM-73 operation included JPL Project Manager Walker E. Giberson, late of Surveyor project management. JPL had only limited experience with external contractors, having contracted only one firm – on the Surveyor programme when Hughes were selected for manufacturing – in all the past 10 years of planetary research. Few persons at JPL had the expertise to negotiate outside work packages so Giberson, one of the last who had worked on Surveyor, was an apt choice. Around him Giberson assembled a competent team of experienced managers; V. C. Clarke took care of mission analysis and engineering, J. A. Dunne became project scientist, J. R. Casani was assisted by N. Wilson in controlling spacecraft-system design and N. Sirri controlled mission operation systems. At Boeing, Edwin G. Czarnecki headed the 1,000-man engineering and development team assisted by Dr. Haim Kennet.

Boeing were working to a stringent budget of less than $50 million for the 30 month programme and by mid-1972 nearly all design and development had been completed. Six months earlier Boeing had modified the original design. The increased temperature profile at the vicinity of the Sun necessitated the protection of photo-voltaic cells used for supplying electric power to the vehicle. To achieve this the spacecraft was originally designed so that its two solar panels could be hinged back 70°, so avoiding full exposure to rays from the Sun. By changing this concept to one in which the extended panels rotated about their long axis the mass dynamics of the vehicle were improved and thermal conduction was reduced. Secondly, all the scientific instruments were relocated so that the Canopus star-tracker would provide a 60° fov versus the 15° fov in the original design.

At this time also, Boeing tested a dynamic model to vibration levels in excess of those anticipated during boost. Most of the activity at Boeing's Kent, Washington, facility were centred in a new four-room complex staffed by ex-Lunar Orbiter/LRV workers. Spacecraft sub-assemblies were built up in the laminar flow room (which Boeing claim is one of the cleanest 1,500 ft^2 rooms in the industry) filtering the air clean of particles larger than 0.3 microns in size. The filters used are 99.7% efficient and provide a super-clean environment for the hooded benches distributed across the floor area. The benches are continually washed with a freshly filtered flow of air and access to the room is gained *via* an airlock. Complete head-to-toe overgarments were worn by personnel working in the laminar flow room, donned and doffed in a change room off the airlock.

The industrial clean area, adjacent to the protected assembly room, contains 9,000 ft^2 of workspace and looks directly into the Spacecraft Assembly Facility. The SAF was used to build up the flight vehicle and was adjoined to a systems test complex equipped with computers and checkout equipment.

By 11 August 1973, Mariner 10 was in Building A0 at the Kennedy Space Center undergoing pre-mate checkout tests. On 25 September, the spacecraft was moved into the Explosive Safe Facility and encapsulated on its launch vehicle by mid-October. The Atlas SLV-3D/Centaur D-1A used for the Mariner mission heralded the first use of such a combination for dual-burn interplanetary missions. With a launch weight of 323,866 lb. the launch vehicle generated 431,000 lb. of thrust at lift-off from Launch Complex 36B. Atlas had been standing on the pad since July 1973, and following installation of the spacecraft a Flight Events Demonstration Test was conducted toward the end of October.

Mariner 10 Flight Profile

Lift-off came at 05:45 GMT on 3 November 1973. The Atlas boost phase lasted more than 4 minutes, accelerating the payload to an altitude of nearly 100 miles and a velocity of more than 8,000 m.p.h. The Centaur upper stage then took over and moved the 1,042 lb. spacecraft to a height of 117 miles and orbital speed of 16,500 m.p.h., shutting down at 9½ minutes into the flight. Following a nearly 30-minute coast phase the Centaur was ignited a second time for more than two minutes, increasing speed to more than 25,400 m.p.h. and altitude to more than 131 miles. The payload shroud had been jettisoned early in the first Centaur boost phase; and Spacecraft separation came less than 2 minutes later followed by deployment of the solar panels, magnetometer boom and high-gain antenna. Residual propellants were vented from the Centaur in a blow-down retromanoeuvre to prevent recontact with the spacecraft or impact with Venus. Less than one hour after launch the Deep Space Station at Canberra had acquired Mariner 10 and within 4 hours the star tracker

had locked on Vega before moving to Canopus.

Within the first three hours of the mission the Charged Particle Telescope and Magnetometer had been switched on, followed by the UVS airglow experiment and the TV cameras. Almost immediately a problem was detected in the TV system. The heaters refused to come on and temperatures dropped. A preliminary failure analysis indicated trouble with a set of switching transistors in the flight data subsystem. This would necessitate keeping the vidicon tubes powered up during the interplanetary cruise portion of the flight when temperatures in the vidicon would stabilise at an anticipated 10-15°F.

On 5 November, at about 20:30 GMT, the Plasma Science Experiment (PSE) was switched on with activation of the scanning electron analyser. Telemetry indicated that the aperture door had opened as planned when a gas pulse was detected from the venting and the photomultiplier detector was duly counting incoming particles. However, these were cosmic ray particles penetrating the structure of the instrument and not electrons and ions in the solar wind. One possible answer lay in the probability of a partially closed aperture door but since the instrument could only get warmer as the spacecraft approached the Sun it was expected to free itself before encounter with Venus.

Beginning less than 17 hours after launch Mariner 10 took several calibration photo's of the Earth and the Moon. These totalled 5 Earth mosaics and 6 Moon mosaics and at 02:50 GMT on 8 November the spacecraft took 84 views of the Pleiades star cluster. By the evening hours more than 900 TV views had been transmitted to DSN stations. Earth/Moon TV views were completed by 02:02 GMT 10 November.

Trajectory Corrections

Several days of spacecraft tracking indicated a biased trajectory targeted for a point 31,000 miles on the sunward side of Venus some 3 hours later than planned. Lewis Research Center reported a bias error in a Centaur accelerometer aligned with the second burn phase thrust line which had produced the misaligned flight path. Mercury 10 mission operations included four planned Trajectory Correction Manoeuvres (TCM's) during the flight phases leading up to Mercury encounter. TCM-1 was scheduled for 10 days after launch with a second TCM opportunity planned for 2 weeks prior to Venusian encounter. TCM-3 and -4 were scheduled for 4 days after encounter and 4 weeks prior to Mercury encounter respectively. Mariner 10 carried a monopropellent hydrazine rocket engine for course corrections using a blowdown technique for the first time.

Both nitrogen pressurant and hydrazine fuel is contained within a 16.5 in. diameter sphere. Blowdown starts at a pressure of 370 psia and decays to approximately 95 psia at depletion, producing thrust levels of 46 lb. to 18 lb. over the 550 seconds burn capability with thrust vector control performed by vanes in the exhaust flow. The 64 lb. of propellent provided a total ΔV capability of 393 ft./sec.

As we have seen, the post-injection trajectory had put the spacecraft on target for a close approach of 31,000 miles to Venus on the sunlit side – the wrong side. Pre-flight trajectories optimised for the required deflection of the flight path at Venus demanded a close approach of 3,600 miles on the dark side of the planet. This would then permit a close approach of about 625 miles at Mercury encounter, six weeks later. To correct the injection anomalies, and perform a satisfactory re-alignment of the flight path, engineers prepared computer tapes for nulling out the error at TCM-1 on 13 November 1973.

Meanwhile, a calibration was conducted on the Charged Particle Telescope and Plasma Science Experiments with both displaying excellent data. The scanning electrostatic analyser was still not reading electron counts, however. The UVS airglow instrument performed an Earth scan late in the evening of 9 November and the TV electron beam was turned off to prolong the life of the vidicon.

The TCM-1 operation got under way at 00:08:32 GMT on 14 November with the roll-turn necessary for spacecraft orientation. Total turn angle in roll was 49.017°, followed by a pitch turn of 127.552°. At 00:42:03 GMT the hydrazine motor was ignited and burned for 19.9 seconds providing a corrective ΔV of 25.4 ft./sec. By 01:08:51 GMT Mariner had reacquired its reference star Canopus, only to lose it again 21 minutes later. Apparently distracted by a bright particle the sensor found Canopus again by 02:40 GMT. Post-TCM tracking indicated a satisfactory trajectory to within 970 miles of the desired fly-by altitude of 3,600 miles. TCM-2, to be performed two weeks prior to encounter with Venus, would null this slight margin and put back pericentre time by 3 minutes. Distance from Earth during the manoeuvre was 2.5 million miles.

A potentially serious anomaly was observed during preparations for a roll calibration manoeuvre. During activation of the gyro's the spacecraft data-handling logic circuitry was reset indicating an impending power problem. The Power-On Reset (POR) occurs when the Flight Data Subsystem clears the memory register for protection against low-voltage inputs. The observed POR indicated either a load sensitivity or a coupled response to an off-nominal configuration. Immediate failure analysis indicated an adequate recognition of spacecraft status by the on-board systems and ground controllers developed a work-around procedure for future roll calibration manoeuvres. Several days earlier, on 21 November, an unexpected drop in temperature was observed when the scan platform was unlocked but this was back to normal by the end of that week. By 28 November Mariner 10 was 5.5 million miles from Earth, 48.1 million miles from Venus, orbiting the Sun at a solar reference velocity of 59,800 m.p.h.

[To be continued

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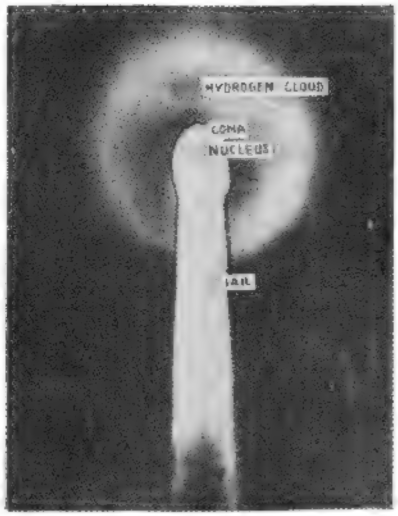
THE PHYSICAL PROPERTIES OF COMETS*

By Professor A. J. Meadows†

Introduction

The purpose of this paper is to construct the simplest possible model of a comet that still reflects the main observed physical properties. Most cometary models assume the occurrence of some currently unobservable process. This complication is circumvented by employing a phenomenological model, based on the observations, which is only related to a more detailed cometary model as a final stage.



Features of a comet.

United States Information Service

The Appearance of Comets

Comets are most obviously distinguished from other objects in the Solar System by their variations in brightness and related changes in size and shape. These variations – as recent experience with Comet Kohoutek reminds us – are often highly unpredictable. It seems reasonable, therefore, to concentrate a discussion of the properties of comets initially on this aspect of their behaviour.

Large variations in brightness can be separated into two categories, of which the easier to observe is the gradual brightening of a comet as it approaches the Sun (and the corresponding fading as it recedes). This sort of change is usually expressed as an inverse power law of distance from the Sun. The average value of the index (n) for all comets is ~ 3.3, but there are wide deviations from this figure. Comet Bennett (1970 II), for example, had $n \sim 5.0$; whilst, at the other extreme, even negative values have been found (i.e. the comet becomes fainter as it approaches the Sun). Moreover, the value of n can vary for an individual comet during the period it is under observation; thus, for Kohoutek, $n \sim 4$ shortly after discovery, decreasing to $n \sim 3$ two months before perihelion. When the comet finally disappeared in the glare of the Sun, the index had decreased further to 2.2. Round about perihelion, Kohoutek brightened considerably – according to the observations made by the Skylab astronauts – but rapidly faded again. On the outgoing leg of the orbit, the comet was consistantly one magnitude fainter than at corresponding points on the incoming leg.

As these data make clear, the brightness variations in a comet cannot be explained purely in terms of reflected sunlight, even allowing for changes in the geometry of a comet as a function of distance from the Sun. Internal changes relating to brightness must also take place.

The second type of brightness variation consists of rapid fluctuations, with periods varying from days to months. A recent example occurred in 1973 when Comet Tuttle-Giacobini-Kresak brightened by a factor of 10,000 in less than a week, fading back to its original magnitude in slightly over a month. This was followed in a few days by another similar outburst [1].

Major brightness changes in a comet, such as we have been discussing, are virtually always accompanied by appreciable alterations in its size and shape. Minor variations in these latter two factors, occurring on a timescale of hours or days, have little effect on the overall brightness, but are observed so frequently that they provide the bulk of our information on cometary changes. Hence, in terms of understanding cometary properties, it can reasonably be argued that small variations are more characteristic of comets than large variations, and should therefore receive more attention.

Gas Tails

In discussing the nature of comets, we will look at the gas and dust components separately.

We can envisage the gas as originating in a sphere which expands and ionises under the influence of solar radiation. The neutral gas can expand freely, but on becoming ionised its motion relative to the circumambient solar magnetic field is constrained in all directions except along the field lines. This would be sufficient in itself to extend the cometary gas into a cylinder; but the typical cometary shape is achieved by further interaction with the solar wind, which is flowing out from the Sun along the field lines. The wind limits the extension of the gas in a sunward direction, whilst assisting in its extension in the opposite direction (by interaction between the cometary and the solar wind plasmas). The magnetic field intensity and the density and velocity of particles in the solar wind vary with distance from the Sun, as, of course, does the intensity of solar radiation. We must expect that the cometary variations described in the previous section will depend on the interplay between these various factors as the comet-Sun distance changes.

This picture of gas (or Type I) tails suggests that many of their characteristics should be describable in terms of MHD interactions and, especially, of MHD instabilities. For example, we have envisaged a comet as a cylinder of plasma devoid of magnetic field surrounded by an infinite expanse of plasma pervaded by a magnetic field. This immediately suggests that a displacement of the cometary cylinder, caused, for example, by some change in the velocity or direction of the solar wind, might lead to the establishment of MHD oscillations [2]. The fundamental period of such oscillations can be estimated as $\sim \ell/v_A$, where ℓ is the length of the gas tail and v_A is the appropriate Alfvén velocity. If we insert values of the parameters corresponding to conditions at the distance of the Earth's orbit from the Sun, we find fundamental periods of the order of a few days. This seems to fit the observational data quite well: Comet Burnham (1960), for example, was observed to undergo tail oscillations with a period of $3^d.9$ at 1 AU [3]. (It should be added, however, that this MHD argument has been disputed. Wurm [4] believes that the 'tail-wagging' is an apparent effect only, caused by ion-streaming.)

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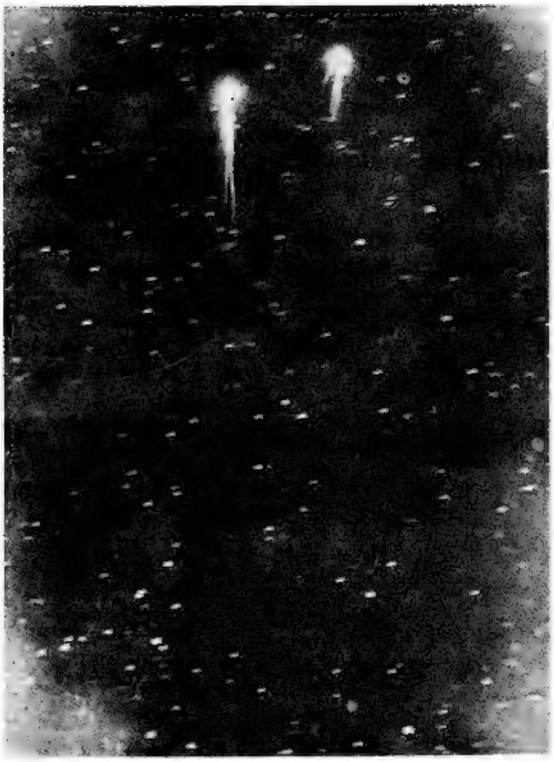
* *Digest of a paper "Studies of Comets" presented to a meeting of the British Interplanetary Society in London on 4 November 1974.*

† *Department of Astronomy and History of Science, University of Leicester.*



Comet Morehouse, Melotte, 1908. Photo shows two stages of development.

The Science Museum, London. Crown Copyright Reserved

The simple picture of a comet as a gaseous ball constrained by a magnetic field may also provide a clue to some of the rapid changes in brightness described in the first section. The interaction with the solar wind produces a coma that is roughly hemispherical in the direction towards the Sun. Under normal conditions, the bow-wave in the solar wind caused by this hemisphere corresponds to a fairly mild shock. Large fluctuations in the solar wind can, however, lead to more severe shocks, and these will be focused towards the centre of the hemisphere. Hence, under some circumstances, energy can be fed into the central regions of the gas sphere. Although insufficient in itself to explain all the brightness variations we have noted previously, this mechanism is capable of acting as a trigger leading to the release of greater quantities of energy. This depends on the hypothesized nature of the central regions, which we will be considering in the final section.

Our model of the gas tail as a plasma cylinder provides a fair insight into the nature of changes in comets, but it must not be pushed too far. In the first place, the strict separation of magnetised and non-magnetised plasma is unlikely to reflect accurately the real situation. Secondly, we have neglected the neutral component of the gas, which recent observations show to be of considerable importance.

Dust Tails

The exact way in which the gas tail and the solar wind interact is still a matter for controversy. The belief that cometary dust tails can be explained in terms of a straightforward balance between solar radiation pressure and solar gravitation has, on the contrary, been generally accepted since the 19th century.

We can again imagine the dust as originating in an expanding sphere along with the gas. The expansion of the dust component, in fact, originates with the gas component: in the denser central region of the sphere the gas flow can be treated as hydrodynamic, and the gas is capable of carrying the dust with it as it expands. The sphere of dust then interacts with the solar radiation. Since the latter varies as the inverse square of the distance from the Sun, as does the solar gravitational field, the dust particles effectively move under a reduced gravitational attraction. They therefore leave the sphere, and fan out to form the dust (or Type II) tail.

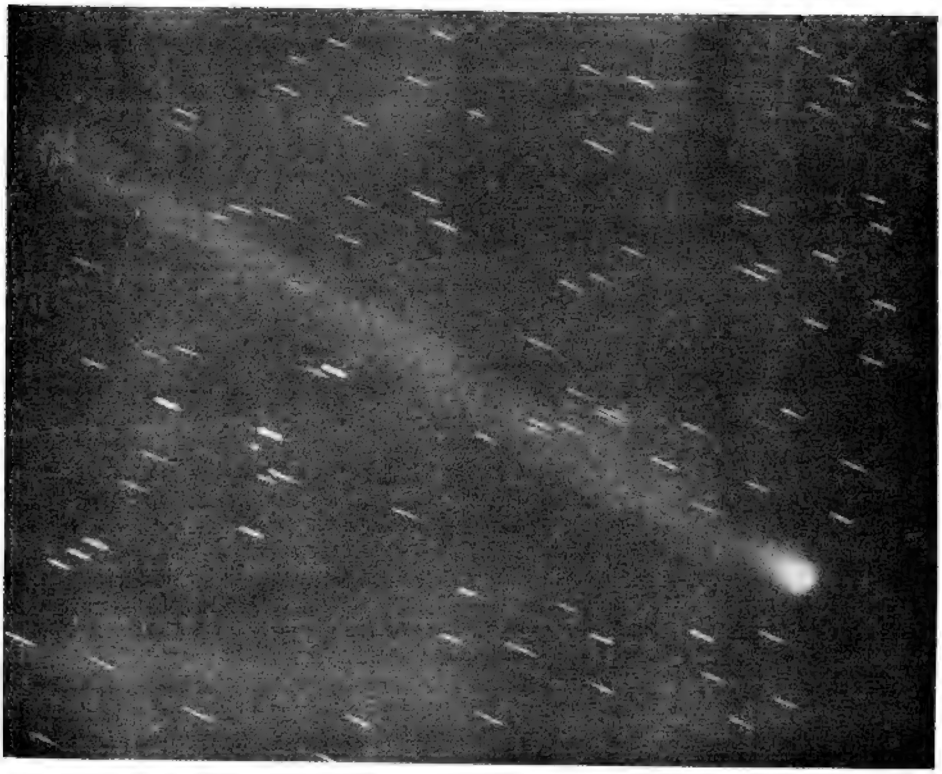
The main problem in describing dust tails in quantitative terms is that a number of poorly known parameters are involved – the size and density of the dust particles and the initial velocity of ejection. Earlier explanations of the dust tail assumed particles of uniform size and density, but with a range of initial velocities (to account for the spread of the tail). In 1958, however, Osterbrock [5] pointed out that, on this explanation, the dust tail should initially be directed radially outwards from the Sun, but that this prediction was not supported by the observations. Ten years later, Finson and Probstein [6] showed that this difficulty could be circumvented by dropping the assumption that all dust particles were of the same size. The resultant description of a dust tail involves quite complicated calculations, since the assumed distributions must be justified retrospectively. Consequently, a detailed comparison of theory and observation has so far only been carried out for three comets.

Although the Finson-Probstein theory seems to provide a reasonable model of dust tails, the fact that it contains a number of adjustable parameters may tend to disguise uncertainties in some of the assumptions. Thus the model supposes that dust particles move outwards uniformly in all directions. As a study of brightness changes in the coma of comets reveals, this is by no means always true: emission of particles preferentially in a single direction has been observed on a number of occasions. Similarly, observation suggests that interaction between gas and dust can sometimes continues beyond the central regions of the gas sphere, and this again must affect the assumption that the initial velocities of dust particles are uniformly distributed in space.

The Cometary Nucleus

The phenomenological approach thus provides a reasonably satisfactory picture of the way in which both gas and dust tails are produced. But it necessarily leaves unanswered the question – how does the expanding sphere of gas and dust originate?

The simplest hypothesis is to suppose that there is some kind of singularity at the centre of the gas-dust sphere that produces both components. This, indeed, represents precisely the most popular cometary model: it is postulated that there exists a solid nucleus, which, by evaporation of gas and dust, provides the observed expanding sphere. Since the nucleus is generally supposed to be too small to be detected by direct observation from Earth, its existence can only be adduced by indirect evidence. In fact, recent confirmation that water vapour forms the commonest molecule in the gas phase [7] also provides evidence for the solid-nucleus theory. The gas spheres we have been discussing make their first appearance



Part of a photograph of Kohoutek's Comet taken at the Royal Greenwich Observatory, Herstmonceux, on the evening of 19 January 1974, when the comet was about 76 million miles (122 million km) from Earth. Instrument used was the 6-in. aperture *f*/4.5 Franklin Adams telescope. Exposure was of 30 min. duration (18^h10^m to 18^h40^m U.T.). The telescope was moved during the exposure so as to follow the apparent motion of the comet across the sky. At the time the photograph was taken Comet Kohoutek was in the constellation Pisces.

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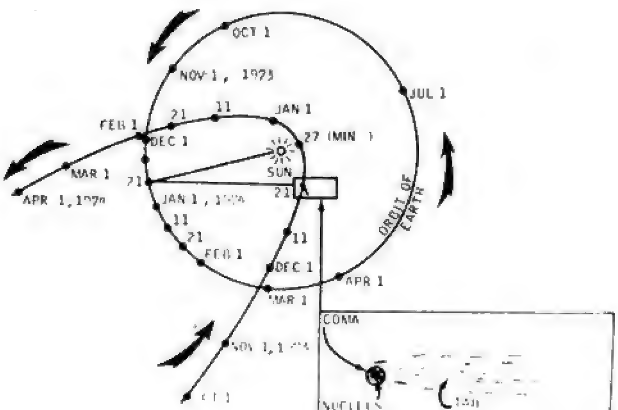

Orbit of Comet Kohoutek.

United States Information Service

at a distance of some 2 AU from the Sun. This can be understood in terms of solar heating only if the material being vaporized is water ice: other types of 'ice' would begin to vaporize at different distances. Hence, Whipple's 'dirty snowball' hypothesis [8] seems to provide a reasonable description of the supposed cometary nucleus.

It would, nevertheless, be much more satisfactory to observe a nucleus directly, and this is one of the important reasons behind proposals for a space mission to a comet. The most attractive opportunity for such a mission is undoubtedly presented by Comet Halley at its apparition in 1986. Comet Halley is not only a bright, long-lived comet (and so the presumed possessor of a large nucleus), but it also has a well-determined orbit. Unfortunately, its retrograde motion implies high encounter velocities, which rule it out – at least for the first mission of this kind. It appears that the initial fly-by would need to be of a short-period comet moving in a direct, well-observed orbit. In these terms, the most likely candidate for identification of a nucleus is Comet Encke in 1980.

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JAFFE HEADS I.A.F.

Leonard Jaffe, NASA's Deputy Associate Administrator for Applications, was elected president of the International Astronautical Federation (IAF) at its 25th International Astronautical Congress held in Amsterdam.

Jaffe began his career with NASA when he joined its predecessor, the National Advisory Committee for Aeronautics (NACA) in 1948 as an aeronautical research scientist at the Lewis Flight Propulsion Laboratory (now Lewis Research Center) in Cleveland, Ohio.

AMES RESEARCH CENTER

By Mike Howard

Introduction

During the years 1927 to 1939 NASA's predecessor, the National Advisory Committee for Aeronautics (NACA), had as its president Joseph S. Ames. To further aeronautical studies, in 1940 NACA established a new field installation at the southern end of San Francisco Bay near Mountain View, California. In honour of NACA's former president the site became the Ames Research Center.

Ames' Activities

The 365-acre Center is built on land contiguous to the U.S. Naval Air Station at Moffett Field with which it shares runway facilities. It comprises some 34 major technical facilities and laboratories which are employed in research activities connected with aeronautics, physics, space, and the life sciences.

Aeronautics

Two major aeronautical studies in which Ames is engaged involve Short Take-Off and Landing (STOL) and Vertical Take-Off and Landing (VTOL) aircraft techniques. STOL aircraft require greater aerodynamic lift than is provided by a conventional wing; therefore, Ames has modified a C-8A 'Buffalo' jet aircraft by fitting a specially designed jet-flap wing. With this "augmentor" wing the aircraft requires as little as 500 ft. (150 m) for take-off. Another project in this area utilizes jet propulsion for the additional lift required. Beyond STOL Ames is using its wind tunnels, simulators, and computers to evaluate VTOL lift and various design concepts.

Another important aeronautical study is concerned with minimizing aircraft noise affecting communities living near airports. During the latter part of 1974 a four-engined DC-8 jet transport began using a NASA-developed two-segment landing approach to achieve a 53 per cent reduction in the area subjected to extreme noise levels. A special avionics package enables the DC-8 to commence its landing descent along a slightly steeper glide path than is usual; then on nearing the runway to decrease the path and allow the aircraft to make a normal landing.

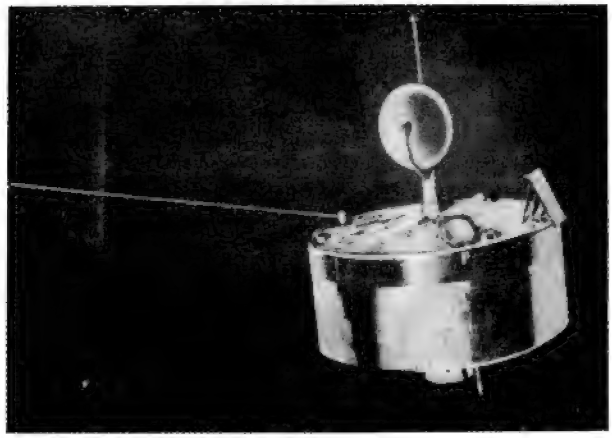
Astronautics

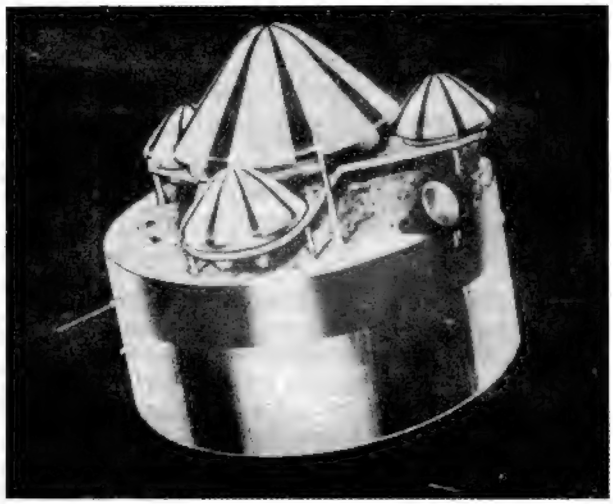
Ames programmes in Space research cover many sciences and disciplines. They include: chemistry and physics of planetary atmospheres; solar physics; lunar and planetary evolution, structure and geology; basic fluid dynamics; problems associated with entry into planetary atmospheres; techniques for obtaining scientific data on the Earth's environment and resources; advanced infrared astronomy; and aerothermodynamics.

Following on from earlier studies on basic atmospheric entry heating and aerodynamic characteristics made in support of the Mercury, Gemini and Apollo programmes, Ames' expertise in this subject is now being applied to the Space Shuttle.

Life Sciences

In the field of Life Sciences it is part of Ames' responsibilities to: investigate the possibility of life elsewhere in the Universe; study the effects of space and aircraft flights on Man and other forms of life; and work to provide environments and equipment for aircraft and spacecraft that will allow crews and passengers to exist safely and perform effectively.



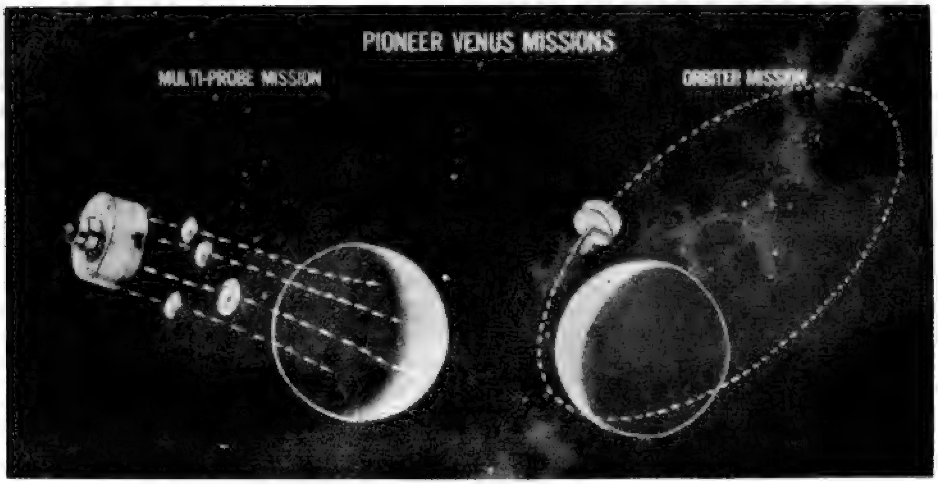


A major project at Ames' is the Pioneer double Venus probe planned for 1978. One craft is designed to conduct its experiments while orbiting the planet; the other *(below)* carries one large and three identical small probes, all to be released at an altitude of about 27 miles (44 km) to descend by parachute to the surface at locations 5,000 miles (8,000 km) apart.

National Aeronautics and Space Administration

In support of the search for life, planetary biologists are studying the methods of formation and evolution of organic compounds. By studying organisms that have adapted to survive in hostile environments on Earth, researchers hope to demonstrate what may have evolved under similar conditions on other planets. As a result of these studies it has become possible to design remote instruments for life detection such as those embodied in the Viking spacecraft intended to soft-land on Mars in mid-1976.

Of especial concern in the medical aspects of the life science studies at Ames is the cause and correction of calcium losses, cardiovascular system deterioration, and radiation hazards in space. In support of the Space Shuttle programme a project to establish the medical criteria for space flight eligibility is at present underway. This will be of great importance when members of the general scientific commu-



Pioneer 1978 Missions to probe the planet Venus. *Multi-probe to investigate:* detailed lower atmosphere composition; detailed lower atmosphere structure; cloud composition and structure; solar radiation penetration; thermal balance; atmosphere circulation and winds; ionospheric composition; solar wind interaction. *Orbiter to investigate:* detailed ionosphere structure; detailed solar wind interaction; planetary scale atmospheric characteristics; surface characteristics; planetary magnetic field; thermal balance; gravity field characteristics.

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nity travel into orbit to man the Spacelab element of the Shuttle.

Air revitalization; purification of water; waste matter processing; food packaging, storage and preparation; and food recycling concepts are a few examples of other space-oriented life science studies being conducted.

Spacecraft

During its history the Ames Research Center has acted as Project Manager for two spacecraft programmes.

One was the Biosatellite, which comprised a family of scientific satellites employed for testing the effects of weightlessness and radiation on biological specimens. Biosatellites were equipped with a re-entry capsule so that the payload could be recovered for post-flight analysis.

The second of Ames' projects is the long-running Pioneer series which began in 1958.

The first group consisted of five spacecraft the last of which, Pioneer 5, was launched on 11 March 1960. All five craft were aimed in the general direction of the Moon on fly-by paths. Pioneer 1, 1B and 2 were launch failures and the remaining spacecraft continued on into solar orbit. However, despite the early frustrations the experiments derived important data on the Van Allen belts, the magnetosphere, solar flares, and the solar wind.

Pioneers 6 to 9 formed the second group which was aimed at deep-space exploration. These four spacecraft were inserted into solar orbit during 1965 to 1968 to return data on solar wind, solar atmosphere, magnetic fields, and cosmic rays. Riding into space in piggy-back fashion with Pioneers 8 and 9 were two NASA Test and Training Satellites, used as tracking targets for the Manned Space Flight Network. In September 1972 Flight Directors for the Pioneer 7 spacecraft set a long-distance record for locating and resuming contact with a spacecraft which had switched itself off. With Pioneer 7 194 million miles (312 million km) from Earth on the other side of the Sun, spacecraft controllers estimated the satellite's position and transmitted the 'turn-on' command to successfully re-activate the craft,

The third group of Pioneers is concerned with planetary exploration. Pioneer 10, launched on 3 March 1972, became the first spacecraft to traverse the asteroid belt as it sped towards an encounter with the giant planet Jupiter. After a 620 million mile journey Pioneer 10 passed Jupiter on 3 December 1973, and will become the first man-made object to leave the Solar System. Estimates suggest it will reach the vicinity of the red star Aldebaran in the constellation of Taurus in approximately 8 million years!

A sister craft, Pioneer 11, set out on a similar journey to Jupiter on 5 April 1973 and encountered the giant planet on 3 December 1974. A course correction in April 1974 had positioned the craft so that it obtained a gravity assist from Jupiter to send it on to the ringed planet. Saturn which should be reached in September 1979.

Future Projects

In 1978 Pioneers 12 and 13 are scheduled to investigate the cloud shrouded planet, Venus. One craft will enter a highly elliptical orbit around the planet while the second will explore the Venusian atmosphere by ejecting one large and three small probes prior to atmospheric entry of the spacecraft. Consideration is also being given to a Jupiter orbital flight during the 1980's using backup hardware from the Pioneer 10 and 11 missions.

Epilogue

During its 35 years the Ames Research Center has seen and contributed to many changes and advancements both in aeronautics and astronautics, and Joseph S. Ames could never have imagined the rapid progress that has been made in both areas in so short a time. The thought of any man-made object travelling at a speed of 110,000 m.p.h. (175,000 kph) – or 30.5 miles per second – would have been unimaginable only a few years ago yet that was the velocity at which the Pioneer 11 spacecraft was travelling as it made its gravitational 'sling-shot' past Jupiter *en route* to Saturn. Thirty five years on from now the Ames Research Center may well have produced, or contributed to, even greater achievements. Whether these involve the tracing of life-forms in space and on the planets, or some advancement in the field of aeronautics, it is certain that Ames will still be in the forefront of such researches.

Acknowledgement

The writer wishes to thank the staff of the Ames Research Center's Office of Public Affairs for their assistance in the preparation of this article.

NASA'S BUSY SPACE YEAR

The Earth, Mars and the Sun will be the focus of U.S. space research in 1975, writes USIS Science Correspondent Everly Driscoll. But as in 1974, the space programme is acquiring more and more of an international flavour.

"More of the World's nations today recognize the benefits of both space science and Earth applications from space more than at any time in the past," says Dr. James C. Fletcher, the NASA administrator. "This growing appreciation is evidenced by the very high level of activity during the 1974-1975 time period."

Of NASA's launches scheduled for 1975, 15 out of 25 are spacecraft of other countries or private U.S. companies, or are joint international missions. In 1974, 12 of 15 launches were.

NASA has a busy 1975 schedule: 25 launches, up ten from 1974. The only manned mission is the joint U.S./U.S.S.R. Apollo-Soyuz docking. The 24 remaining spacecraft include two to the planet Mars; two for the study of the Sun; nine for communications and navigation; four for study of Earth's weather, climate and air pollution; one for study of Earth's resources; one for oceanographic research; and two for astronomy.

Of these, 12 spacecraft are owned by other nations or other U.S. government or private agencies which pay NASA for the launches. These include communications satellites of Canada (Telesat); of West Germany and France (Symphonie 2); two satellites of Intelsat, an international communications consortium of 80 nations; and eight satellites for U.S. organizations.

NASA will also be paid for launching the celestial observation satellite for study of cosmic rays. The satellite is owned by the European Space Research Organization. Two of the U.S. comsat satellites will be for international use: Marisats A and B. These are navigation satellites for communication with ships at sea. The U.S. Navy will lease many of the channels, but the rest will be available for any other world customers.

The two largest international projects this year – Helios B and Apollo-Soyuz Test Project (ASTP) – are cooperative: NASA and another country each pays for part of the expense. Helios B, a West German-built satellite, will take close-up measurements of the Sun. The spacecraft will pass within 26 million miles (41,600,000 km), even closer than its predecessor, Helios A, launched in December 1974. No spacecraft will have gone as close to the Earth's star as the Helios pair.

West Germany built and is managing the spacecraft, although scientists from Germany, Italy, Australia and the United States will analyse the data.

ASTP will be the first joint manned space mission. The purpose is to test a universal docking collar that would make it possible for future manned spacecraft of two nations to dock with each other in Earth orbit for joint activities.

The 10-day mission will begin with the launch of a two-man Russian Soyuz spacecraft from the Tyuratam launch complex in Kazakhstan on 15 July. Seven and a half hours later, a three-man U.S. Apollo will be launched from the Kennedy Space Center in Florida. The two spacecraft will dock after two days in Earth orbit. They will remain joined together for two days, during which time the two crews will visit each other's cabins.

After undocking, the Soyuz will return to Earth. If all continues to go well, the Apollo may remain in orbit for six more days while the astronauts conduct various scientific experiments.

In 1974 the number of NASA launches paid for by other countries or cooperative with NASA was even higher: 12 of 15. Five of the six scientific launches were cooperative. These were Helios 1, the solar spacecraft with Germany; Ariel 5, an X-ray astronomy satellite with the United Kingdom; ANS, an ultraviolet and X-ray astronomy satellite with Italy. Another 1974 launch carried three satellites, two of which were international. One was a Spanish satellite, Intasat, for measuring the electron content of the Earth's ionosphere. The other was Amsat-Oscar, an amateur radio satellite for Australia, Canada, West Germany and the United States.

Many of the NASA missions for 1975 will have broad international appeal and use even though NASA is paying for the missions. Earth will be the centre of attention.

The second Earth Resources Technology Satellite (ERTS 2) was launched in January. ERTS-1, launched in July 1972 and still operating, drew unprecedented international participation and interest. It has already radioed back more than 100,000 images covering most of the Earth's surface. These have proven useful in a variety of tasks such as monitoring urban development and land use, identifying crops and geologic formations, locating air and water pollution, updating maps and navigation charts, measuring snow cover and tracking flood waters.

Scientists from more than 40 countries and several international organisations have been involved with interpreting and using the results. But international interest goes beyond even this. Brazil and Canada through an agreement with NASA have built ground stations to receive ERTS data about their own country directly from ERTS. Italy is now building one.

NASA recently launched the second synchronous meteorological satellite SMS-2 which has been stationed above the Pacific Ocean to keep watch constantly both day and night and through cloud cover on weather developing in that area. (SMS-1 is stationed over the Atlantic). These pictures are made available to an ever-growing network of weather stations in many countries of the world.

The Earth's atmosphere will also be probed by two atmospheric explorers that will focus on the upper atmosphere. Nimbus 6 is also Earth-oriented. It will track the movement of energy from the tropical regions where most of the heat from the Sun is stored to the temperate zones. This movement of heat is responsible for much of Earth's weather systems. Nimbus will also obtain data to determine long-range effects of pollution on climate.

The key element of Earth's weather – the oceans – will be examined by GEOS-C, a geodynamic experimental ocean satellite. GEOS will measure the height of the ocean's surface, which, even without waves, has highs and lows due to changes in the Earth's crustal material.

Also in 1975, the Indian Government will use the new Applications Technology Satellite (ATS-6) for broadcasting television programmes on a variety of subjects to 5,000 villages and cities. ATS, launched in 1974, has been used in the United States for broadcasting educational and medical programmes to people who otherwise are cut off from such services in remote regions.

Three planetary and astronomy missions are also on the

1975 docket. The Small Astronomy Satellite (SAS-C) to study X-ray emissions from objects in the Universe will be launched from the Italian launch platform off the coast of Kenya, Africa, using a NASA rocket. Another Orbiting Solar Observatory, OSO-8, will also be launched from the United States.

The most complex and sophisticated unmanned spacecraft to date – two Mars Vikings – will be launched in August. These craft carry both Orbiters and Landers and will be the first attempt by NASA to soft-land instruments on Mars. The prime experiments will test the Martian soil for living organisms. NASA will try to land the first Viking on 4 July 1976, the 200th anniversary of U.S. Independence.

"It will be a busy international space year," says one NASA official. "Space cooperation has been far more extensive than the public or even governments generally realise," says Dr. Fletcher of the new year. "In fact, we with our collaborators will have invested roughly 1,000 million dollars thus far in space joint projects when the current projects run out – and this does not count either ASTP or the Spacelab (a laboratory being built by Europe to fly in the Space Shuttle in the 1980's).

Dr. Fletcher said the 1974-75 cooperative efforts have meant savings, better science, and less duplication for all countries involved, with "unlimited opportunities to benefit humanity".

WOMEN OF 'SPACELAB'

An all-woman research team has completed a five-day exercise which could lead to the selection of similar teams to fly into orbit with the Space Shuttle. The test was made at NASA's Marshall Space Flight Center in Huntsville, Alabama.

The experimenters, Dr. Mary H. Johnston, Ann F. Whitaker and Carolyn S. Griner, and the crew chief, Doris Chandler, spent eight hours each day of the mission in Marshall's General Purpose Laboratory (GPL), a cylindrical structure (14 ft. wide, 24 ft. long) approximately the size and shape of the European Spacelab.

The laboratory, part of the Marshall Center's concept verification test (CVT), is designed to reduce future costs of experimentation in space by involving potential experimenters early in the development cycle of their hardware. Several other similar exercises have already been tested in the GPL. Dr. Johnston, Mrs. Whitaker and Mrs. Griner have been working on experiments for several months.

Mrs. Chandler, an engineer, was the communications contact between the crew and the "ground station" and, in general, served as administrator and scheduled the daily workload for the mission. Dr. Johnston, who specializes in metallurgical engineering, was the principal investigator for three scientific experiments and co-investigator on one other. Ann Whitaker, a physicist specializing in lubrication and surface physics, conducted three experiments. Carolyn Griner, an astronautical engineer specializing in materials sciences, was principal investigator for five experiments and co-investigator with Dr. Johnston on one other.

The purpose of the exercise, designated "CVT Test No. IV," was to conduct 11 selected experiments in materials science to determine their practical application for future Spacelab missions and to identify integration and operational problems which might occur on actual missions. One experiment was aimed at providing a basis for a standard set of support hardware for future materials science payloads.

Inside the GPL, the four women worked under conditions simulating, as nearly as practical, those which would exist in a space station in Earth orbit, excepting, of course, weightlessness. Air circulation, temperature, humidity and other factors were carefully controlled. Their communication with the "ground," actually only a few feet away outside the GPL, were the same as it would be if they were in Earth orbit. Their "shirtsleeve" environment allowed them to wear jumpsuit-type clothing during the mission.

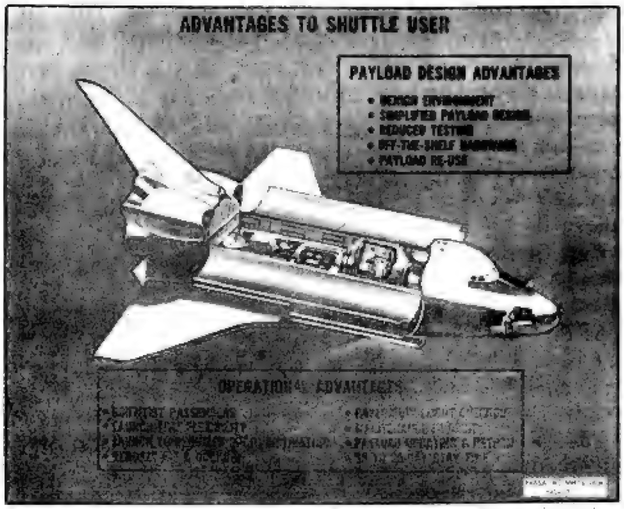
All four agree that women can play an active role in future space programmes. "There are plenty of qualified women available for scientific-type missions," Mrs. Chandler said. She added, and the others agreed, that right now women's roles are primarily scientific, but that there is no reason why women couldn't do almost any job a man could do in space in the future, including pilot, technician or even construction worker.

Mrs. Chandler said her daughter, who is now a senior in high school, plans to enter college next year and major in engineering with a goal of working in the space programme.

The crew chief admits frankly that she wants to fly a real mission in Earth orbit. She said her husband is all for it and is encouraging her in her work. In the back of her mind is the not-impossible dream of a mother-daughter scientific team on a future space mission.

Mrs. Whitaker, whose husband is also a physicist and employed by the Army, said he thinks the current test is great. As to an actual space flight, Mrs. Whitaker said her husband would be "proud to see me go – for a while – but probably wouldn't want me gone too long."

Mrs. Griner's husband, a physicist employed at Marshall, is all for the simulated mission, she said, and would like to be a part of such a mission himself. "As for my making an actual space flight," she said, "my husband might not like for me to go on a long mission – like a 400-day trip to Mars – but I believe he would go along with the idea and not object. There would certainly be no objection to a



Space shuttle offers numerous advantages beyond the purely scientific and economic: international research teams – men and women – can be flown into space routinely.

National Aeronautics and Space Administration

Spacelab mission."

Dr. Johnston, a simulator veteran of two previous tests and the only unmarried woman in the crew, said she would welcome an actual flight. She believes her doctorate degree improves her chances of getting an actual mission."I am convinced," she said, "that a woman could do any job a man could do on a space flight – including piloting the Shuttle – if we are allowed to go. "Personally, I want to see what effect weightlessness has on metals in the liquid state and solidifying. I am interested in solar processing. There is unlimited opportunity to produce unique materials in space by taking advantage of the vacuum, weightlessness and solar energy we have out there. It (Spacelab) is a laboratory no scientist would want to miss using – any scientist would want to go."

U.S. EXPERIMENTS IN SOVIET BIO-SATELLITE

NASA will propose life sciences experiments for flight aboard the next available Soviet biological satellite under an agreement announced last December. The agreement, ratified by NASA and the Soviet Academy of Sciences, calls for the U.S. to propose one or more self-contained experiments.

NASA, which has already prepared detailed descriptions of the proposed experiments, will deliver flight hardware for those designated no later than 15 August 1975, just one month after the U.S. Apollo and Soviet Soyuz are launched for tests of a new universal docking system.

The first American flight experiments will be passive specimen modules placed in standard containers developed for the Soviet biological satellites. These containers have a volume of slightly less than 2800^2 cm (0.5^3 ft.). Each U.S. experiment will be completely autonomous from Soviet spacecraft power, life support, and data recording systems and will require no operational commands from the ground during its flight.

Dr. David Winter, NASA Director for Life Sciences and chairman of the U.S. delegation, says that the most likely candidate experiments will be those concerned with fish embryo development, plant and tissue studies. One of the small containers housing U.S. experiments may be mounted inside a centrifuge to provide artificial gravity as a scientific control.

Dr. Winter has requested Dr. Sheldon Wolf of the University of California, San Francisco, to serve as chairman and to appoint an *ad hoc* committee to evaluate the scientific merit and technical feasibility of experiments being proposed by the life sciences directorates of NASA's Johnson Space Center, Houston, and Ames Research Center, Mountain View, California.

Dr. Wolf is co-chairman of the Committee on Space Biology and Medicine of the Space Science Board, National Academy of Science.

The recently signed protocol includes a provision for U.S. investigators to participate in pre- and post-flight studies of blood and tissue samples from animals which the Soviets will fly aboard their next biological satellite.

NASA scientists will also review and report to the Soviets early next year with suggestions for proposed future flight experiments using animals to study the biological role of gravity.

Other areas of mutual interest for biological experiments during the next two or three years are those relating to artificial gravity, vestibular experiments, bone and tissue demineralization, cosmic radiation effects, and processes involved in tissue regeneration during weightlessness.

The next meeting of the Joint Working Group on Space Biology and Medicine will be held in the United States during the second half of 1975.

SYMPHONIE IN ORBIT

The Franco-German Symphonie experimental communications satellite achieved geo-stationary orbit above the west coast of Africa following the firing of the on-board apogee motor on 21 December 1974. Communications tests are now in progress.

The launch took place from Cape Canaveral, Florida, at 9.39 p.m. EST on 18 December using a Delta launch vehicle, with the spacecraft achieving transfer orbit close to that planned for subsequent injection into synchronous orbit.

However, one launch vehicle anomaly did occur in the Delta Inertial Guidance System (DIGS). Approximately nine seconds following completion of the DIGS guided portion of the flight, the Inertial Measurement Unit (IMU), which is the attitude sensing portion of the guidance system, stopped functioning. This anomaly had no effect on the Symphonie 1 flight. Delta officials are reviewing the data to establish the cause and institute appropriate corrective action.

VIKING'S STUDENT EMBLEM

When America's Viking spacecraft touches down on the surface of Mars about 4 July 1976, it will be carrying an emblem designed by an American student. The opportunity to design the emblem was offered to students by the National Science Teachers Association, in cooperation with NASA, through a nationwide contest.

Together with the student emblem, the Viking lander will display the American flag and the American Bicentennial design. The three will be painted on the dust shield, which covers the radioisotopic thermoelectric generators (RTG's) that power the lander.

Other emblems have been associated with the Viking project, but will not fly on the spacecraft. The student-designed emblem was specifically designed for the spacecraft.

BRITAIN IN COMSAT REVOLUTION

In an average month this year, close to one million telephone calls will be relayed around the world to and from Britain *via* Intelsat satellites – conversations between business contacts, relatives, and friends passed crisply *via* orbiting space-age "switchboards" 22,300 miles high over the Atlantic, Pacific and Indian Oceans. European television viewers can look forward to seeing live "as it happens" pictures in their homes direct from tennis championships in Texas in April, the Olympic Games in Montreal in 1976, figure-skating from Japan in 1977, and the latest foreign news events – thanks again to the satellite revolution in communications.

As six Intelsat 4 "international" communication satellites bring the world literally to Britain's doorstep this year, a new generation of orbiting relay stations is being prepared which will be capable of nearly doubling the traffic of the network – with Britain contributing a major share in its development and production.

Technicians of British Aircraft Corporation Electronic and Space Systems Group, employed on what is effectively Europe's only production line for commercial satellite systems, have been building the main structure and vital parts of the systems for a "second generation" Intelsat, the 4A, the first scheduled for launch over the Atlantic this July.

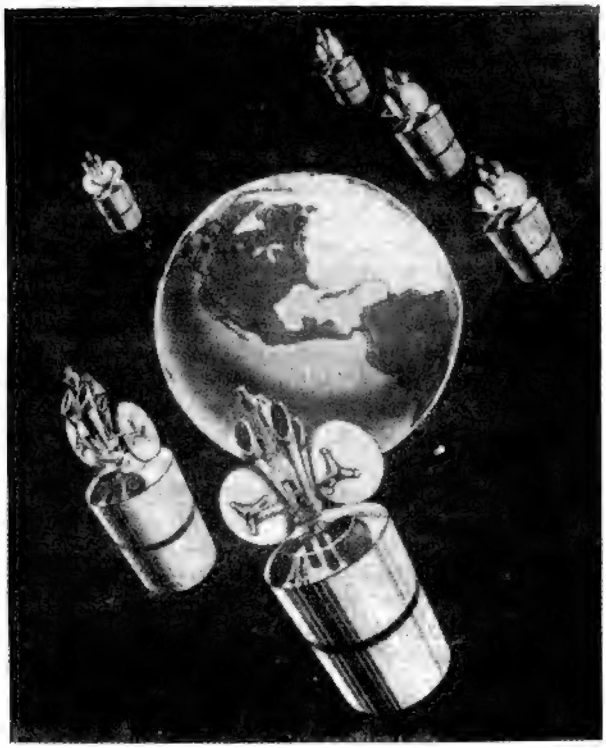
With international telephone and cable traffic expanding at a rate of twenty per cent each year and expected to double over four or five years, the two active Intelsat 4's over the Atlantic, that over the Indian and fourth over the Pacific (with reserves over the Atlantic and Pacific and an earlier Intelsat 3 standing by against need over the Indian Ocean) are already approaching full capacity*.

Expanding use of such satellites is reflected by the fact that today they serve 81 Earth stations in a total of 59 countries. Over 100 dish transmitter/receivers now "tune in" day (and night) to bounce messages through space, taking no account of the military networks.

As main overseas contractor to Hughes Aircraft Company of California, British Aircraft Corporation has helped pioneer the Intelsat communication satellite series from its earliest days and has been manufacturing commercial satellite systems since 1969. More recently the British company has won a contract to produce major sub-systems for the United States' national satellite system to be operated by the Comsat General Corporation and leased by American Telephone and Telegraph.

Virtually all the main structure of the six Intelsat 4 satellites built to date, as well as important parts of the power system including solar arrays, batteries, wiring harness, reaction control systems and Sun sensors, have been provided by BAC. Additionally, it has supplied similar structures and components for two more due to be launched this year and is building three sets of sub-systems for the new Intelsat 4A series.

While Intelsat 4's can handle up to 5,000 telephone conversations or 12 colour TV channels, the new 4A generation will have a capacity for 9,000 telephone or up to 20 colour TV channels, overtaking equipment developed only five years ago. Domestic satellites for the United States in BAC contracts will carry 28,000 voice circuits.



A picture that brings home the social impact of space technology – the "necklace" of Intelsat 4 satellites that now rings the Earth following the launch of a sixth satellite from Cape Canaveral on 21 November 1974. The new Intelsat 4, built by Hughes Aircraft Company, was launched by an Atlas Centaur towards a geostationary orbit above the Pacific as a back-up to a similar satellite launched in January 1972. Contributing to the huge success of this commercial network of global communications has been the British Aircraft Corporation's Electronic and Space Systems Group, now busy on Intelsat 4A systems.

* *A seventh Intelsat 4 was being launched into geo-stationary orbit above the Indian Ocean, as we closed for press.*

SUN-EARTH EXPLORER

A £1¼ million contract under a project for scientific exploration in space has been won by BAC's Electronic and Space Systems Group. The contract from the European Space Research Organisation (ESRO) is for the development of satellite sub-systems for the International Sun Earth Explorer Satellite System.

Previous satellite missions have revealed the main features of the Earth's magnetosphere. But its dynamic behaviour and the influence of the solar wind upon it are still largely unknown.

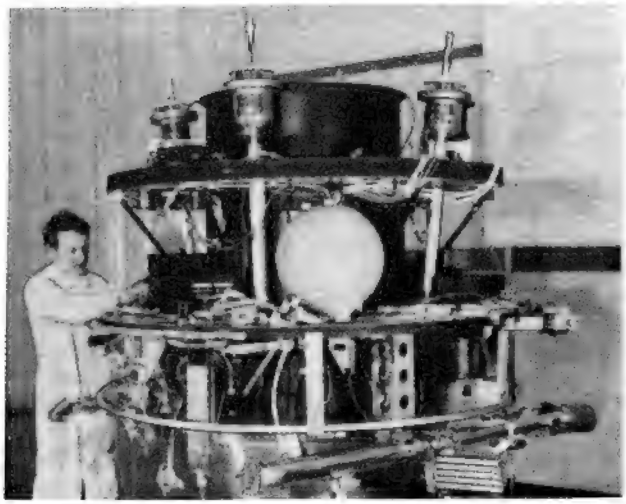
The three planned spacecraft missions in this latest joint NASA/ESRO programme will close this scientific gap. Two of the satellites, ISEE-A and ISEE-C, are being developed under NASA auspices.

The third, ISEE-B, is the responsibility of ESRO, with Dornier Systems as prime contractors. BAC is to develop the spacecraft's attitude and orbit control sub-system consisting of sensors, hinged booms for sensor deployment, control electronics, and a reaction-jet system which will establish the satellite's attitude and position in space.

BAC will also develop the satellite's mechanical ground support equipment and be responsible for tests on the satellite's structure.

Satellites ISEE-A and ISEE-B equipped for similar experiments will be launched by a single Thor Delta rocket in the autumn of 1977. They will travel at a carefully-controlled and variable distance from each other of 100-5,000 km in a highly eccentric orbit close to the ecliptic plane.

The third satellite, ISEE-C, to be launched one year later, will go into solar orbit and monitor the solar wind undisturbed by the Earth's presence.



Engineering model of GEOS satellite.

British Aircraft Corporation

BAC AND GEOS

Above is the first photograph of the development "model" for Europe's first geostationary scientific satellite, GEOS. The model is being assembled at Bristol by BAC's Electronic and Space Systems Group.

GEOS is under development by the STAR consortium of companies under the prime contractorship of BAC. The model brings together for the first time the many sub-systems from the consortium, together with the on-board experiment apparatus from the nine scientific groups taking part.

Purpose of the model is to make sure all these contributions are compatible before the satellite is built. GEOS is due to be launched in 1976 to probe the electric, magnetic and particle fields in the Earth's magnetosphere.

MEADOWLARK FLIES HIGH

A new research rocket successfully launched by the British Aircraft Corporation could have a wide export potential. Called Meadowlark it is designed primarily for scientists probing the ionosphere and the Earth's magnetic field; but it is capable of carrying a variety of different scientific instruments.

A major advantage of the new two-stage rocket is that its design benefits from the enormously successful Skylark sounding rocket although the cost, without the payload, will be about £20,000 i.e. some £10,000 less than Skylark.

Meadowlark was designed, built and flown in nine months by B.A.C. Electronic and Space Systems Group engineers, with the assistance of the Royal Aircraft Establishment and the Science Research Council. Based on well proven rocket motors it embodies the experience gained over 18 years of continuous development which made Skylark, with 330 launched to date, the most reliable sounding rocket of its size in the world.

Designed to meet the requirement of scientists investigating geophysical phenomena at altitudes up to 220 miles (350 km), Meadowlark can give a 110 lb (50 kg) payload eight minutes of useful experiment time. It uses the Goldfinch first stage motor used by Skylark, followed by a 10-in. (25 cms) diameter Gosling motor as the second stage in place of Skylark's 17 in. (43 cm) Raven motor. Total length is typically 22 ft. (6.7 m) compared with Skylark vehicles which often exceed 30 ft. (9.1 m).

On its proving flight the prototype Meadowlark reached a height of 170 miles (272 km) carrying a 115 lb. (52 kg) payload. All flight sequences operated exactly as planned and the performance achieved indicates that the production version will meet its performance specification. The payload prepared by the Royal Aircraft Establishment carried instrumentation and an experimental electronic timer, developed by the Science Research Council's Appleton Laboratory, which operated successfully in the rocket environment.

Although the proving flight was made from the Skylark launch tower at Woomera, Meadowlark is capable of using any of the types of rail launcher currently in use for rocket launching in different parts of the world.

SEA SATELLITE

Sea Satellite (SEASAT), a new programme for monitoring the oceans to provide continuously updated reports on weather and sea conditions, has been announced. Responsibility for managing the 2,100 lb. (954 kg) spacecraft which will circle Earth 14 times a day in a north-south orbit, has been assigned by NASA's Office of Applications to the Jet Propulsion Laboratory (JPL), Pasadena, California.

The launch in 1978 of SEASAT-A will be a 'proof-of-concept' mission, which could lead to operational missions in later years. The concept of such a satellite has been carefully evolved since 1973 in cooperation with other government agencies and private institutions interested in and knowledgeable about the oceans.

Instrumentation in a sensor module, which forms a part of the satellite, will provide data from which wave heights, current directions, surface wind direction and surface temperatures can be determined. These data will allow for the recognition of storm, sea state, currents, ice fields and specific weather conditions.

The sensor module is the responsibility of Wallops Flight Center, Wallops Island, Virginia, with support by the Applied Physics Laboratory of Johns Hopkins University, Silver Spring, Maryland. As currently planned the module will consist of four primary sensors: a compressed pulse radar altimeter, a coherent synthetic aperture imaging radar, a microwave wind scatterometer, and an infrared radiometer.

Each of the four sensors will be managed by a NASA research centre. The radar altimeter will be the responsibility of Wallops; the microwave wind field scatterometer will be managed by the Langley Research Center, Hampton, Virginia, and the synthetic aperture imaging radar will be directed by JPL. The visible and infrared scanning radiometer is an existing instrument, and Goddard Space Flight Center, will monitor the technical development. Goddard will also be responsible for data acquisition and satellite tracking support.

The objective of the initial mission will be to demonstrate the capability of continuously acquiring a wide variety of accurate oceanic data and rapidly disseminating the informa-

tion to users concerned about weather predictions, routing of shipping to avoid storms, adverse currents and ice fields, and coastal disaster warnings. An operational network of satellites could provide individual ships at sea with twice-daily detailed maps of their specific route, noting weather conditions, sea state and hazards. Long-range use of satellite data could influence ship design, port development and selection of sites for such off-shore facilities as power plants.

In addition to immediate applications of satellite data to such uses as hazard and storm warnings, SEASAT will also accumulate scientific data on the curvature of the oceans; ocean circulation; transport of mass, heat and nutrients by surface currents; and the interaction between air and sea.

The approximately one-ton satellite, to be supported by aircraft, ships and buoys to verify measurements reported from space, will orbit Earth in an 480 miles (800 km) orbit inclined at 108° to the equator.

In establishing the requirements of the satellite system and to carefully define the types of information that would be of practical use, NASA was supported by a SEASAT User Working Group composed of representatives from the Departments of Commerce, Defense and Transportation; the National Academy of Sciences; the National Science Foundation; the Smithsonian Institution's Astrophysical Observatory; the Woods Hole Oceanographic Institute, Mass.; Scripps Institute of Oceanography, California; City University of New York; and several commercial users.

The programme will use an off-the-shelf NASA or Air Force spacecraft, to which the sensor module will be attached. Existing NASA tracking facilities and support hardware will allow for the forming of a complex programme without new technology. Cost of the SEASAT-A mission, as currently planned, is $58.2 million.

ATM IN SPACELAB?

A Solar Physics Working Group held a three-day meeting at the Marshall Space Flight Center recently to consider new advanced solar physics missions. Among topics was a proposal to convert the Skylab Apollo Telescope Mount (ATM) backup hardware to an early solar physics payload for Spacelab to be launched in the NASA Space Shuttle.

ERTS-2 IN ORBIT

ERTS-2, the companion to one of the most celebrated satellites in U.S. space history, was launched into Earth orbit on 22 January at 1756 GMT from the Western Test Range in California.

ERTS-2, which stands for Earth Resources Technology Satellite, is expected to at least equal the record of ERTS-1, which is still operating. ERTS-1 has far surpassed even the most optimistic pre-launch hopes of three years ago. During its 29 months in orbit, ERTS-1 has returned more than 100,000 images, covering all of the United States and most other parts of the globe.

"If I had to pick one spacecraft, one space age development to save the world," said Dr. James C. Fletcher, the NASA Administrator "I would pick ERTS and the satellites which I believe will be evolved from it later in this decade."

Speaking before the United Nations World Food Conference in Rome last year, Secretary of State Henry A. Kissinger called the ERTS experiment "A promising and potentially vital contribution to rational planning of global production."

ERTS is international in scope and mission. Any nation can obtain the data taken over its own territory. The spacecraft circles the globe every 103 minutes taking measurements over a 114 by 115-mile swath. The data, when processed, is useful in many studies including agriculture, forestry, marine resources and biology, land use, geology, water resources and air and water pollution. The data can be processed into images, but can also be used in a variety of other computer studies.

As the Earth rotates beneath the polar-orbiting satellite, the same regions of the globe come beneath the spacecraft every 18 days. This allows researchers to note changes and make comparative studies of the same region year-round. The sensors aboard ERTS-2 are identical to those on ERTS-1.

Scientists from more than 40 nations have been actively involved in analysing the data for their countries since the launch of ERTS-1 in July 1972. An equal number will participate in the ERTS-2 analyses. Canada and Brazil already have ground facilities to receive and process data about their country directly from the U.S. satellite. Italy and Iran are constructing such facilities. At least eight other nations have expressed interest in building ground stations.

SALYUT 4 EXPERIMENTS

Although Soviet cosmonauts have a long way to go before they equal the 84-day record set by the Skylab astronauts in February 1974, the recent 30-day mission of Lt-Col. Alexei Gubarev and flight engineer Georgi Grechko – most of the time aboard the Salyut 4 space station – demonstrates a continuing Soviet enthusiasm for Man-in-Space.

Indeed, there is every prospect that the Russians will make considerable headway whilst American astronauts are 'grounded' between the ASTP mission this year and the time when the Space Shuttle flies around 1980, writes Kenneth Gatland. Their Salyut stations are being built on a production line with new equipment being introduced for a wide range of significant experiments which we understand later will include the processing of materials.

Salyut may be only about one-third the size of Skylab but considerable development is taking place within the overall programme. For example, we now know that the Russians are building a robot version of the Soyuz ferry to fly to space stations unmanned for the purpose of re-supplying an already manned Salyut with fuel, oxygen, food and other consumables. This was the meaning of the two-day flight of Soyuz 15 last year which failed to dock with Salyut 3; the cosmonauts were testing the automatic docking system.

Other clues to the nature of Soviet plans may be judged from experiments carried out on board Salyut 4 by the first boarding party.

Among the most interesting and important experiments were those related to development of closed-cycle life-support systems which will have wide future application – in large space stations, interplanetary spaceships and extra-terrestrial bases.

In the ceiling of Salyut 4, peas sprouted in a "cosmic garden". The cosmonauts observed the growth of chlorella in a nutrient medium and replanted micro-organisms in a special cultivator. Soviet scientist Alexander Kamin des-

The Soyuz 17 cosmonauts who boarded the Salyut 4 space station and set a new Soviet record for manned space flight of nearly 30 days: *left*, Lt-Col. Alexei Gubarev; *right*, flight engineer Georgi Grechko.

cribed the apparatus as a "cosmic factory" producing albumen and oxygen which served to lay the basis for a necessary future space industry. In time the Russians say they will use higher plants and chlorella (microscopic algae) to generate oxygen for cosmonauts to breathe whilst absorbing carbon dioxide.

Gubarev and Grechko also tried out a system for condensing water from the cabin atmosphere, and actually used the recycled water for drinking and in the preparation of their food.

Other experiments supervised by Grechko were concerned with genetics, embryology and physiology. They involved bacterial cultures, fruit flies, fertilised frogs spawn and samples of hampster tissue.

Orbiting 210 miles (338 km) above the Earth Gubarev and Grechko photographed large areas of the Soviet Union and other countries. They used automatic apparatus to measure the transparency of the atmosphere in the UV and IR parts of the spectrum in order to assess the amounts of water vapour and ozone present. Ozone is one of the most important atmospheric constituents; its 'biological shield' protects all living things on Earth from damaging UV radiation.

The Sun was another important research target, as it was for the men of Skylab. Salyut 4 carries a 9.8 in. (25 cm) solar telescope, with spectrograph and diffraction spectrometer, specially built for the station at the Crimean Astrophysical Observatory. The cosmonauts actually resprayed the primary and secondary mirrors of the telescope which had been 'dulled' by three weeks' exposure in space. The solar telescope is housed in an unpressured 'funnel' in the large section of the space station (see drawing of Salyut-Soyuz in the February issue of *Spaceflight*, pages 60-61) which in low-altitude missions may house a long-focus camera for Earth observation as an alternative payload (item 17 in drawing), with the station turned 180°.

Andrei Bruns of the Crimean Astrophysical Observatory explains: "Particles of matter, individual molecules, are still encountered at a height of 200-300 km. These particles, moving at a tremendous speed, knock out of the skin of the spacecraft microscopic particles around which a sort of micro-atmosphere, a cloud of fine dust, is created. These particles stick to the cold surface of the mirror together with condensed vapours.

"On the Earth, telescope mirrors are renovated in special vacuum chambers in which a new reflecting coating is deposited at approximately $\frac{1}{10}$th micron thickness. In the Salyut 4 experiment the designers made use of the natural conditions of space vacuum. The spraying of both mirrors – primary and focusing – was directed by Grechko from a remote control console.

Until this problem is solved, said Academician Andrei Severny, head of the Crimean Astrophysical Observatory, there would be no sense in sending into orbit telescopes of the next generation with mirror diameters of one and three metres.

Salyut 4 also has a Filin X-ray telescope to scan the star fields for radiation which might fix the position of pulsars and neutron stars. The apparatus consists of an external platform with X-ray detectors linked in parallel with the small telescope. Any bursts of X-rays registered by the counters can thus be tied to a specific celestial body.

The cosmonauts also tested for Ukranian scientists compact cryogenic equipment to cool the infrared telescope spectrometer which involves an 'ice coating' of solid nitrogen. The technique, developed at the Kharkov Physical-Technical Institute of Low Temperatures, is considered vital to the development of extra-atmospheric astronomy.

Everything points to the Russians developing larger space stations and their own Space Shuttle for the 1980's. Academician Boris Petrov, the noted Soviet scientist and expert in automatic control, forecasts a space station with a 10-year life capable of housing replaceable crews of 10 to 12 men. He suggests that they will be assembled in orbit from "plug-in" modules launched separately by large rockets and propelled into position by Space Tugs.

EROS PHOTOGRAPHED

Seventy photographs of the planetoid Eros (18 km across) were obtained in February by Soviet astronomers during the close approach. Eros, discovered in 1898, this year came within 23,600,000 km of the Earth. Sideral period is 1.76 years; orbital inclination 10.8°.

A HISTORY OF THE SATURN I/IB LAUNCHERS

By David Baker

Introduction

The story of the Saturn Programme begins in April 1957 at a time when the first Atlas ICBM was being prepared for flight, before the formation of NASA, and before the first artificial satellite had been sent into orbit.

Atlas, the then most powerful missile in the western world, could muster about 300,000 lb of thrust and realisation of the deficiencies in heavy missiles prompted the US Army Ballistic Agency (ABMA) to begin studies of a liquid propellant booster using a cluster of conventional rocket motors producing a total thrust of 1.5 million pounds. Over the following 18 months more than 50,000 man-hours were to be expended on these studies.

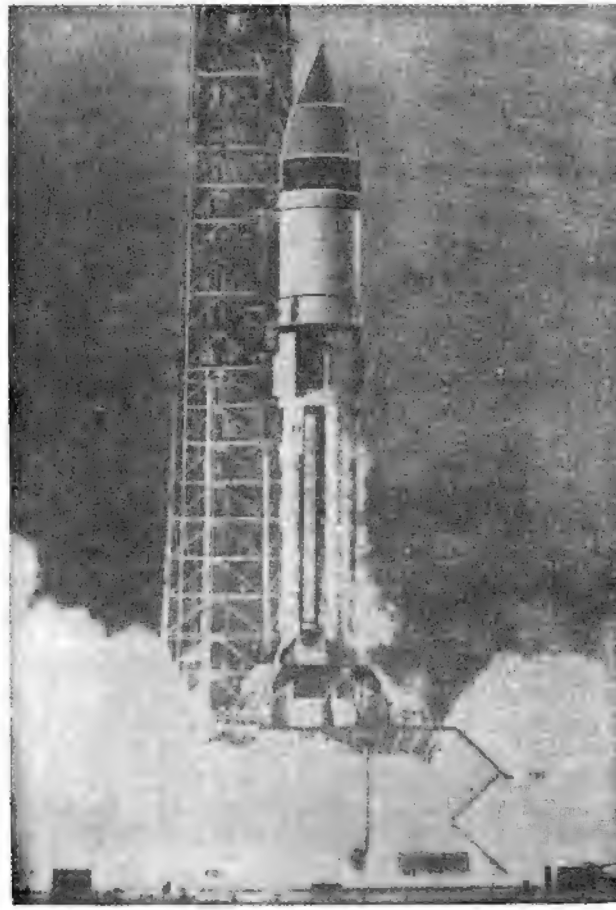
By mid-October Dr. Werhner von Braun, director of the Development Operations Division was pressing for a substantial increase in the US commitment to space with development of a large booster. In talks with Maj. Gen. J. B. Medaris, the ABMA commander, a national space policy emerged endorsed by the Army Scientific Advisory Panel.

On 10 Dec. 1957, the ABMA released its proposals for 'A National Integrated Missile and Space Vehicle Development Programme' including plans for a short-cut approach to the heavy booster. Through the expenditure of $850 million, funding 30 R & D flights, the Army would possess a booster for manned and unmanned flights, hopefully by 1963.

In hearings before the Senate Preparedness Investigating Sub-committee on 14 Dec. Gen. Medaris testified: 'Unless this country can command 1 million pounds of thrust by 1961, we will not be in space. One of the great holes in the ballistic missile business today is that there is no big ballistic engine or rocket engine under development'.

Dr. von Braun added weight by pointing out the superiority of Russian rocket power urging recognition of the major gaps in US rocketry. At the same hearing Gen. Medaris was asked why steps had not been taken to implement a recommendation of the 1956 Silverstein Committee that a 300,000 lb thrust engine be developed. His only reply was that, 'it disappeared in the Department of Defence'.

By 10 Jan. 1958, the Sub-committee heard of the development of a Russian single-chamber engine of 800,000 lb thrust and by the 23rd of that month they had concluded the hearings and issued a 17-point plan for American Security including an immediate start on 'a rocket motor with a million pounds thrust', and an acceleration in research and development programmes through the establishment of an independant agency.



Saturn I lifts off from the Kennedy Space Center on 5 July 1966 to place its own 29-ton second stage into orbit. The mission was to find out if supercold hydrogen fuel could be controlled for space use. A TV camera monitored the behaviour of 10 tons of fuel in the 90 ft. long tank to prove it could be ready to re-start rocket engines in space, an essential requirement for landing Apollo astronauts on the Moon.

United States Information Service

One Million Pounds of Thrust

Just 7 days after the first US satellite was placed in orbit on 31 Jan. the Advanced Research Projects Agency (ARPA) was formed to create a working environment for space oriented hardware, and by the end of February the Preparedness Sub-committee heard reasuring news. Secretary of Defence McElroy testified: 'work on a rocket motor with a thrust of 1 million pounds or more is progressing through the necessary preliminary stages. If an engine of this thrust should be required before the proposed single-chamber becomes available, the requirement can be met by clustering several engines of smaller thrust which the Air Force has in a more advanced stage of development. Even though there is some question as to whether the latter method may not be the best way to achieve these large thrusts, we expect to continue development of the single-chamber one-million pound engine so that we will be able to meet any future requirements for the multi-million pound levels of thrust by means of the clustering technique with the large engine'.

The machinery was nearly complete and on 31 Mar. the Army Ordnance Missile Command was established in the final link of the chain toward preparations for the heavy boosters anticipated. Realising the significance of the new ocean in space President Eisenhower authorised the establishment of an independant space agency – NASA – on 2 Apl. 1958.

This was the height of 'missile-mania'. Doubtful projects were dreamed up by over-zealous military minds and even moved Gen. Medaris to state before the House Select Committee on Astronautics and Space Exploration: 'I believe that the US Army must make long range plans for the transport of small combat teams by rocket. Cargo transport by rocket is economically feasible'.

It was the prospect of firing teams of men halfway round the world that gave stimulus to the big booster cry and first placed the seeds of thought on manned rocketry before Washington.

By 18 July 1958, the ABMA were stressing the 1.5 million pound thrust clustered booster with strong support from the von Braun team who first conceived the idea. One month later the Advanced Research Projects Agency (ARPA) authorised the Army Ordnance Missile Command (AMOC) to proceed with the heavy booster under project direction from the ABMA at Redstone Arsenal, Huntsville, Alabama. Juno V, as the project was called, in the original plan, was to have used four 330,000 lb thrust Rocketdyne E-1s but ARPA advised the adoption of eight 150,000 lb thrust motors of the Rocketdyne MB-3 class. The engine had the advantage of being used in the Thor and Jupiter IRBMs, was well-proven, fully tested and readily available.

By this time the Air Force were working on the development of a high-energy stage called Centaur and this was suggested as the third stage of Juno V for launching military payloads.

Captive firings were scheduled for 1959. By 11 Sept. 1958 a contract had been signed with Rocketdyne for the development of the H-1, a re-modelled MB-3, and within 2 weeks ARPA and AOMC had confirmed their desire to use an expanded Juno V as the first stage of an advanced launch vehicle.

On 23 Sept. Mr. Johnson, Gen. Medaris, and associated ARPA and AOMC personnel met to draw up development plans. General agreement was reached to expand the programme from 1 to 4 boosters with a propulsive flight test by Sept. 1960, followed by 3 more. To accomodate this increased level of interest funding went from $13.4 million in 1959 to $20.4 million in 1960.

NASA was activated on 1 Oct. with speculation as to the ultimate future of the AOMC. In the event, it was nearly 18 months before the ABMA development division could be transferred to NASA. In a published document entitled, 'Juno V Space Vehicle Development Programme (Phase 1)', the AOMC were not reluctant to draw attention to the meagre fiscal appropriations, accusing Washington of running a 'compromise' programme.

As of Dec. the flight schedule anticipated the first flight in Oct. 1960, a second in Jan. 1961, the third in June and the fourth in Oct. To maintain this schedule a decision would have to be made within 3 months on the vehicle's second stage.

Juno V Upper Stages

By Nov. 1958 the go-ahead had been granted for 4 flight test vehicles. Before the year was out Rocketdyne had test-fired the H-1 at Canoga Park, and a combined AOMC/Air Force Review Committee were strongly recommending to the newly formed NASA that Juno V be adapted for further expansion and application to advanced space missions. The upper stages for Juno V were considered from a range of missiles just emerging from the drawing boards and the ARPA came out in favour of Atlas as the second stage, providing a payload capability of 25,000 lb.

On 3 Feb. 1959 it was decided to drop the name Juno in favour of Saturn. Coming from the Jupiter stable Saturn was a fitting designation as the next planet out in the Solar System.

Personnel at AOMC began to press the ARPA for a go-ahead signal on development of the upper stage configuration for Saturn. They recommended that second stages with payloads should be scheduled for the third and fourth flights with a request for a further extension up to 16 vehicles, considerably increasing the investment and growth potential.

By Mar. the AOMC completed their analysis of 1,375 possible configurations for upper stage design and pressed for an early decision, citing their preference for an Atlas or Titan. On 19 Apr. Roy. W. Johnson, director of ARPA, announced that Titan would be used as the second stage to Saturn. Early in the following month the first H-1 had arrived at the ABMA facility in Huntsville and was test fired for 80 seconds, achieving its first long-duration burn of 151.03 seconds on 2 June.

Also in June the ABMA were recommending a Saturn C-2 booster possessing a 2 million pound thrust first stage, 1 million pound thrust second stage, and a 200,000 lb thrust third stage for lunar landing duties. Yet very soon the entire programme was to be fighting for its life.

Based on the assumption that there would be no increase in appropriations for FY 1960 the AOMC pessimistically forecast a shift in the completion date for the 4 initial test flights to Jul. 1962. Optimum funding would have seen the fourth flight in Oct. 1961, within a year of the first planned launch.

On 9 June Dr. York refused a $6 million increase in Saturn funds. The conflict grew and on 24 July ARPA were offered 2 alternatives, both within a $70 million budget for FY 1960. Only minimal effort would centre on upper stages and the SA-1 first stage would proceed at a leisurely rate toward assembly. A programme of only $130 million for FY 1961 would result in a full year's slippage, costing the agency an additional $100 million overall, a year's budget of $250 million being required to pull back just 6 months.

What looked like the final blow came on 29 July when the Director of Defence Research and Engineering cancelled Saturn on the grounds that Titan could perform all the tasks desired by the Army/Air Force team. The ARPA stopped work on the adaptation of Titan to second stage duties, and bitter conflict ensued. The Pentagon saw vast sums draining from their purely ballistic missile programme and Huntsville, under von Barun's influence, was dedicated to providing a heavy space booster. Von Braun was heard to comment more than once that he had been stifled by govermental 'stop-go' policies before!

Meanwhile efforts were made to get the programme back on track and Dr. von Braun presented 3 potential levels of funding to the ARPA. These plans would require a total expenditure of from $854 million to $946 million depending upon annual peak funding levels. In the lowest paced programme the initial availability of Saturn vehicles for NASA missions would not come before winter 1964: at the nominal level it could be achieved in the second quarter of 1962.

From 16-18 Sep. 1959, a combined ARPA/NASA Booster Evaluation Committee sat to compare the Saturn and Titan programmes, finding Saturn to have the greater payload capability and operational flexibility. Already development funds for Saturn during the current fiscal year had been cut by 50% and but for the existence of NASA the project history would probably have ended there,

However, on 21 Oct. President Eisenhower decided to transfer the ABMA Development Operations Division and its 5,000 personnel to the space agency, effective 15 Mar. 1960, thus enabling it to concentrate on 'one powerful booster'. The Army was free to develop Titan, and NASA the Saturn. Administration of Saturn would be under the

ARPA with work conducted by the ABMA.

The Booster Evaluation Committee discovered that in an effort to accelerate work on Titan III-C the contractors had deliberately underquoted engine costs, estimates had excluded the entire hardware cost for the test flights and no consideration had been given to the lower payload capability and longer development time compared with Saturn. The Saturn Programme was reaffirmed.

In Nov. the Research Steering Committee on Manned Space Flight discussed the use of Saturn in NASA programmes and confirmed the C-1 for earth orbital operations and an Advanced Saturn for lunar landings. At about this time ARPA and NASA asked the Army Ordnance Missile Command for studies on a new upper stage configuration for the early Saturn with liquid oxygen/liquid hydrogen propellents. They provisionally advised use of four 20,000 lb thrust engines in the second stage and 2 of the same in the third stage. These were later to be called the S-IV and S-V respectively, Already the period of indecision had caused a two-month slip in launching the first Saturn, SA-1.

By the end of 1959 NASA had formally accepted this configuration and planned for a 10-vehicle programme to be followed by a larger Saturn in 1967 capable of orbiting 85,000 lb or sending 25,000 lb on an escape trajectory.

Origin of 'Apollo'

In Jan. 1960 the follow-on to Project Mercury was named, albeit informally. At a luncheon in Washington Abe Silverstein, then the Director of the Office of Space Flight Programmes, suggested the name 'Apollo' after discussing with friends the new advances in knowledge that he anticipated for the coming years. It was to have a profound effect on the entire Saturn Programme.

On the 18th of that month the Saturn was approved as a programme of highest national prioity and accorded the DX rating, originally requested more than 14 months earlier.

With the way now clear for development of the large booster, Saturn got a 'shot in the arm' from a generous proposal for funds in Fiscal Year 1961, starting July 1960. The budget advanced the entire Project by 1 year, cutting the test schedule by 3 to 9 months. Two vehicles would be launched in 1962, and 1963, three in 1964, and four annually from 1965 to 1969. It was proposed that Agena B and Centaur vehicles would provide upper stage propulsion until the S-IV and S-V became operational. By 29 Feb. in fact, 11 companies had submitted proposals for the S-IV.

In Mar. the preliminary schedule began to harden. Static tests would begin that spring with a first flight on dummy upper stages in the summer of 1961, a two-stage capability by autumn of 1962, three-stage flights late in 1963, and a fully operational Saturn C-1 by 1964.

On 28 Mar. two of the eight H-1s grouped in the test model SA-T at the newly named George C. Marshall Space Flight Center, Huntsville, were fired for 8 seconds, opening the static phase. One month and one day later all eight H-1s were fired for 9 seconds, developing an unprecedented 1.3 million pounds thrust.

Handling Problems

For the first time the Western World had a booster that gave promise of eclipsing the Soviet launch vehicles, but at a price. In an effort to spread the work over several States, and at the same time take advantage of existing facilities, the Saturn stages posed a major transportation problem. With a length of more than 80 ft and girth of nearly 22 ft the Saturn became the subject of handling studies examined at a conference late in Mar. 1960.

If the major structural components were disassembled it would require 9 road transporters or 11 aircraft to shift the S-1 between manufacturing, test and launch sites. In a fully assembled configuration, and this it should be stressed refers only to the first stage, only water transportation would provide the answer. In the interests of economy and engineering practicality it was the latter that would ultimately by chosen. Another discussion point at this time was the use of a possible parachute recovery technique.

Payload Capability

During these early months of 1960 much thought was given to the payload opportunities presented by a growing family of heavy space boosters. Voyager flights to orbit Mars and Venus were assigned to Saturn for the 1965-67 period and lunar soft landings with roving vehicles and sample return craft found practicality under the heavy lift promise from the Saturn C-1.

The long drawn out argument over upper stages for the Saturn had, till now, been centred on either the B-1 configuration or the C – series. The B vehicles would have used RP-1 and LOX in upper stages whereas the C – series used LH_2 and LOX. Now the B-1 configuration became defunct and attention centred on the cryogenic propellent stages with NASA studies on these concepts from AOMC.

Events now began to accelerate as,in May, assembly of the first flight booster SA-1 began at MSFC, the SA-T was given a public demonstration in a full thrust 35.16 sec burn, and work began under a NASA contract to Rocketdyne on the 200,000 lb thrust J-2, an engine designed to burn a LOX/LH_2 combination and serve for upper stage propulsion.

With SA-T testing completed by 15 June the Apollo spacecraft (then a Mercury follow-on for orbital and circum-lunar missions) was suggested for the C-1. Boilerplates could test structural design concepts and validate the system, At a conference held in May the Advanced Manned Spacecraft was determined to require compatability with the upper stages of the Saturn C-1 and C-2. By the end of April Douglas Aircraft had been selected for production of the S-IV on Saturn C-1 and the contracted work began in July.

The adequacy of the C-1 for all projected NASA missions came in serious doubt at a Saturn Study Committee meeting on 30 Sept. and recommendations were made to contract for an S-II stage for the C-2, an advanced Saturn that would use higher-thrust upper stages. The C-1, it was said, would be limited to placing a 5,100 lb payload on translunar flights and even at this early stage the translunar module of Apollo (not yet a lunar landing programme) was up to 8,000 lb. George M. Low testified that the C-2 would be capable of achieving these requirements and gave weight to the argument that the C-2 was, in fact, the more useful proposition.

It seems to have been at this point in the evolution of the Saturn class that the C-1 was, in theory at least, relegated to a development posture for these larger boosters.

On 25 Oct. the C-1 flight schedule was written-up. The first flight with dummy S-IV and S-V stages would be made in mid-1961, two-stage flights would begin in early 1963, with the full configuration space-borne by the end of that year. The first 10 research and development flights would be completed by early 1964, clearing the way for the first flight of the C-2 by 1965. An earlier proposal to put Agena B and

Centaur stages on early flights was not adopted.

The New Year saw the first contracted studies aimed at reusability for the S-I stage. North American Aviation Incorporated and the Ryan Aeronautical Company each took a close look at the possible use of a Rogallo Wing for recovery. The later Gemini spacecraft was to be test-dropped with this device in studies of a land-recovery technique. The Rogallo Wing is deployed like a parachute and assumes the profile of a high thickness/chord ratio delta configuration with the device in question suspended beneath on nylon lines. The lift characteristics provide a controlled descent, or glide, to a soft landing.

By early 1961 the basic design of the C-1 and C-2 had been drawn up. The C-1 would ultimately fly with eight H-1 engines in the first, or S-I stage, four P & W LR-119s of 17,500 lb thrust each in the second, or S-IV, stage, and two similar engines in the third, or S-V, stage. The C-2 was now seen as being available in four or three-stage variants. In the former the third and fourth stages would be taken from the C-1s second and third stages. The first stage would remain the same but an intermediate 800,000 lb thrust second stage, or S-II, between the 1.3 million pound thrust S-I and 70,000 lb thrust S-IV was as yet uncontracted. The three stage C-2 would use the S-I, S-II and S-IV only.

Months earlier plans were laid for a C-3 vehicle but this would await development tests of upper stages and a more advanced mission schedule from NASA.

By the end of March NASA had approved the substitution of the four LR-119s for 6 of the older LR-115s at 15,000 lb. thrust each for the S-IV stage. As early as 25 Jan. von Braun was trying to get the C-1 relegated to a two-stage booster with deletion of the S-V and he was instrumental in getting sanction from President Kennedy for increased funds for the C-2, enabling it to be ready by 1964. Funds were also available in the proposed FY 1962 budget for contracts to be awarded on the 800,000 lb thrust S-II stage.

A new role for Saturn, that of launch vehicle for the Air Force's Dyna-Soar manned re-entry glider, was examined closely. Titan II had already been selected as the prime launch vehicle but funded appraisal of the Saturn for an advanced Dyna-Soar had been underway at this time.

On 29 Apr. 1961 the first C-1 booster, SA-1, was flight qualified with a 30 second test of all eight H-1s. The way was cleared for the maiden flight of a booster 4 times more powerful than anything yet launched in the Western World. At last it seemed that an up and coming space programme would raise the Western powers into a position of superiority. The fact that this outcome was held up as a torch in the dark by visionary politicians may explain the apparent ease with which the elements of an elaborate assault on the Solar System were rapidly formed.

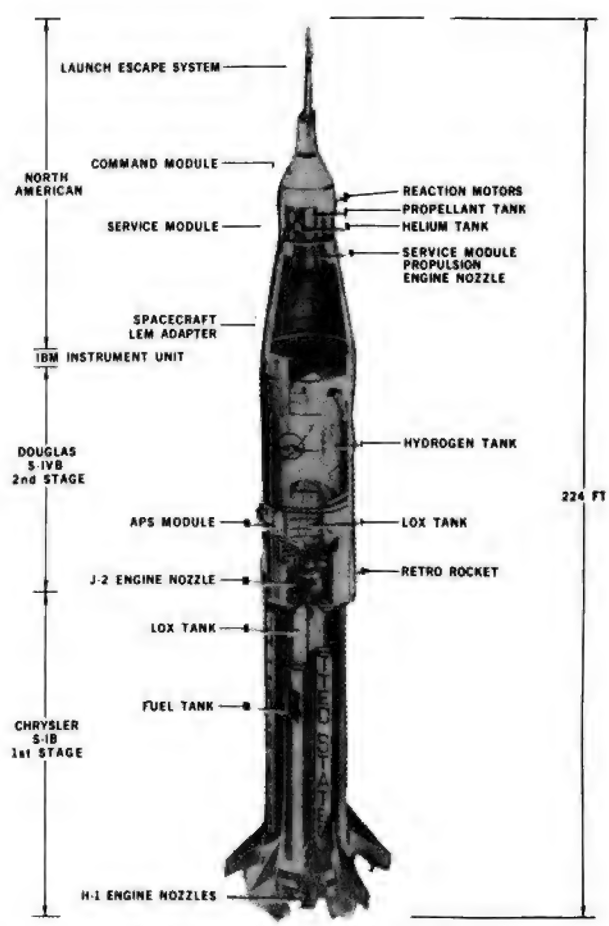
To The Moon!

One of the most profound decisions regarding the entire future of the American space programme was building up during May 1961. NASA were asked to present recommendations to the President that would enable the US to achieve pre-eminence in space, demonstrate to the World that America was technologically second to none, and direct public attention away from the political wrangles with Russia. NASA Headquarters advised the White House that a manned lunar landing could be achieved by 1967 and on 25 May President John F. Kennedy publicly announced that the nation would go for a landing on the Moon before the turn of the decade.

Already NASA was thinking of using a higher thrust first stage for the projected C-3 and the new demands on heavy booster technology forced by the President's decision caused a re-look at the C-2 and C-3 concepts. Just 8 months after the Saturn Study Committee had recommended the C-2 as being capable of providing Apollo with a circumlunar capability the Marshall Center decided that a Saturn of greater lifting capacity would be required for manned flights around the Moon.

On 1 June NASA announced major changes to the Saturn C-1 programme. The S-IV second stage would be introduced on the fourth mission with dummy upper stages. Vehicles SA-7 to SA-10 would launch Apollo boilerplate models having increased tankage area to contain an additional 100,000 lb of propellent with fins attached to improve aerodynamic stability. The S-V third stage would only be used after the first 10 research and development flights. Under the accelerated Apollo Programme the C-2 would be used for circumlunar flights.

An Ad Hoc Task Group was formed on 20 June to lay plans for a lunar landing mission using the Saturn C-3 in Earth Orbit Rendezvous. A direct launch to a direct landing on the Moon was favoured but a vehicle of the C-3 class could be used to assemble modules for a launch to a direct landing



Saturn IB with Apollo Command and Service Modules.

National Aeronautics and Space Administration

from Earth-orbit. The so-called Nova, possessing a cluster of F-1s in the first stage, was cited for the direct launch mode. Workers at the Langley Center devised a plan to use a C-3 for a Lunar Orbit Rendezvous. In this operation a separate lander would detach from Apollo to descend to the lunar surface, later to rendezvous again for the return to Earth. They proposed 2 landers for a total spacecraft weight of 79,500 lb.

The flight schedule for the C-1 was modified to incorporate an SA-1 launch in late 1961, with vehicles SA-2 and SA-3 launched in 1962, five C-1s in 1963, and the ninth and tenth in 1964.

By the 23rd of June work on the C-2 was brought to a halt and effort concentrated on the C-3 and Nova. Both of these would use a different first stage than the C-1. The Rocketdyne F-1 engine was allocated to these larger boosters, with a thrust of 1.5 million pound per unit. The scene was set for the hottest debate that NASA has probably ever had to face as the agency was confronted with the choice of 3 modes of approach to a lunar landing: Direct Ascent, Earth-Orbit Rendezvous, or Lunar-Orbit Rendezvous.

The final decision on which method Apollo would use was still a full 18 months away. It was to be the heavy booster situation that would ultimately decide the outcome after deep discussion, some political embarrassment and a considerable amount of bickering.

Political committal to a decade of space achievements was rubber stamped with a massive 61% increase in the Fiscal Year 1962 funds for NASA approved by the Congress on 28 June 1961.

It is fitting here to make brief mention of the intermediate C-4 model, formulated during the long summer of 1961. It was proposed that four F-1 engines would power the first stage (6 million pound total thrust), with an S-2 (800,000 pound thrust) and S-IV (60,000 pound thrust) mounted above.

Thus were arraigned the 6 heavy boosters proposed for filling the liquid propellent launch vehicle class beyond Atlas.

On 15 Aug. 1961, the first stage for SA-1 completed a 10 day, 2,200 mile journey from Huntsville to Cape Canaveral. The first flight was little more than 2 months away.

Following deletion of the C-2 in the June of 1961(see above) attention focused on the projected C-3 and by mid-August it was decided to use two F-1s in the first stage, four J-2s in the second stage and six LR-115s in the third stage. This would provide a 100,000 lb payload capability to orbit or 38,000 lb on an escape trajectory. The following month North American Aviation were awarded a contract for fabrication of the S-2. An economical analysis pointed up the adaptability of the C-3 by proposing a grouping of such vehicles to provide a modularised Nova class proulsion system.

As early as 28 July Requests For Proposals had been issued to 12 companies for Apollo based on the assumption that Phase A of the lunar landing programme would use the developed C-1 for Earth-orbit trials, The C-3 for circumlunar tests, and clustered C-3s or a single Nova class vehicle for the actual landing, through Earth-Orbit Rendezvous or Direct Ascent respectively.

Pressing ahead with their proposals for the Lunar Orbit Rendezvous technique the Space Task Group pointed out the possibilities for a modified Mercury spacecraft to achieve a lunar landing using the Saturn C-3. The Ad Hoc Task Group, however, were favouring the Earth-Orbit Rendezvous method, pressing the need for a C-4 class vehicle to achieve this objective.

The limitations imposed by the single-minded committal to a manned lunar landing played an important role in eliminating those variants of Saturn that would serve no useful function for Apollo. This would ultimately, and for all time, limit heavy boosters for unmanned work to solid-propellent classes.

To return to the central theme of Saturn evolution, a Marshall Space Flight Centre – Space Task Group team held discussions on 3 Oct. and decided to replace the 6 LR-115s originally slated for the S–IVB with a single J-2 of 200,000 lb thrust. The S-IVB was assigned to launch vehicles of the C-3, C-4 and Nova class. This recommendation maintained the continuity of engine assignment following on from the use of the J-2 for the second stages of these advanced Saturn models.

First C-1 Launching

With singular pride, and considerable elation, the Huntsville team achieved the goal toward which they had been working for some 4 years when, on 27 Oct. the first Saturn C-1 ascended from Cape Canaveral. It was mid-morning local time when the heaviest launch vehicle yet launched in the Western World took its 925,000 lb bulk on a 215 mile flight down the Atlantic Missile Range. Both dummy S-4 and S-5 stages were ballasted with 23,000 gallons of water total. A Jupiter IRBM provided the nose cone. The first stage motors burned for less than 2 minutes to propel the vehicle to a height of nearly 85 miles and within 8 minutes the flight was over. Saturn had proved it could fly and NASA had vindicated its path to the Moon.

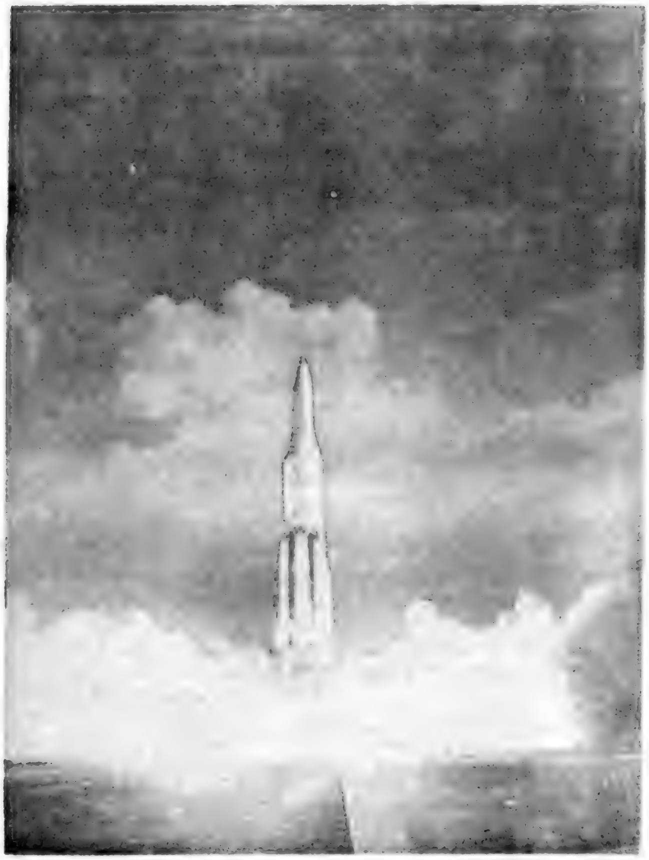
To date some $800 million had been appropriated to the Saturn Programme and NASA was confidently establishing guidelines for the remaining 9 flights of the C-1 development vehicle. Two launches would follow in 1962, five in 1963, and two in 1964. Still holding their 1 June decision NASA anticipated the first two-stage flight for early 1963.

To recap, a C-3/Nova combination, or the C-4 alone, would follow the C-1 for heavy payload missions to circumlunar or lunar landing objectives. C-3 would use two F-1s in the first stage (a total 3 million pounds of thrust), four J-2s in the second stage (800,000 lb thrust), and a six-engine cluster of RL-10s for the third stage (90,000 lb thrust).

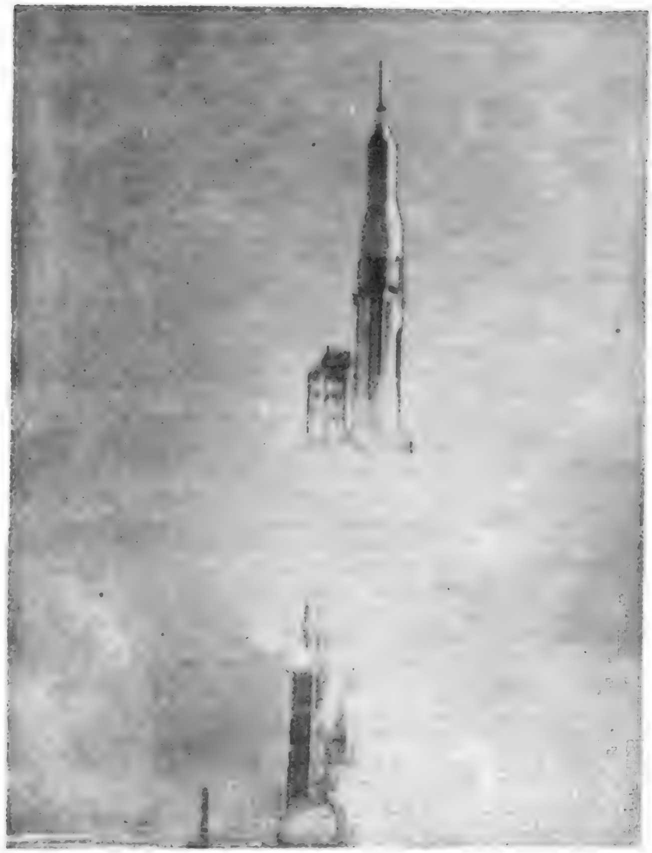
C-4 would be similar to the C-3, with four F-1s in the first stage doubling the thrust to 6 million pounds. Although at this time something of an embarassment the C-5 would use five F-1s in the third stage, with S-II and S-IV upper stages. Payloads to orbit would range from 100,000 lb for the C-3 to 250,000 lb for the C-5, with the latter capable of delivering 70,000 lb to an escape trajectory.

Plans for Nova

By 6 Nov. 1961, the Marshall Center had instructed North American Aviation to add a fifth J-2 to the S-2 stage, uprating it to a full 1,000,000 lb thrust capability. In that month also a NASA study group took a close look at the booster situation as it related to future mission requirements. Primary emphasis for the lunar landing still hung on a Direct Ascent flight using a launch vehicle of the Nova class. This mammoth would carry eight F-1s in the first stage (LN-1) for a lift-off thrust of 12 million pounds, four LOX/LH_2 M-1 engines in the second stage (LN-2) at 2 million pound thrust, four J-2s in the third stage (LN-3) providing 800,000 lb thrust, six RL-10s in the fourth stage (LN-4) thrusting 90,000 lb, and a fifth stage (LN-5) with two RL-10s at 30,000 lb thrust total.



First Saturn I launch vehicle blasts off from Cape Canaveral, Florida, on 27 October 1961. The ballistic flight, which tested first stage of launch vehicle, lasted 8 min. 3.6 sec., reached a maximum of 3,607 m.p.h. and impacted in the Atlantic 214.7 miles downrange. Peak altitude was 84.8 miles.



Eighth successful test flight of Saturn I on 16 February 1965 took into orbit the first Pegasus meteoroid detection satellite. The huge spacecraft, with its wing-like detectors, gathered information on potential hazards of meteoroids to long-duration manned space flight.

National Aeronautics and Space Administration

The all-liquid Nova would lift 600,000 lb to Earth orbit, place 150,000 lb on an escape trajectory, or land 50,000 lb on the Moon by direct descent. Back-up to this concept was the Saturn C-5 with five F-1s, four J-2s and a single J-2 in the first, second, and third stage respectively. This vehicle was slated for the Lunar Orbit Rendezvous mode. The study group saw the C-3, C-4 and C-5 as candidates for the Intermediate Large Launch Vehicle.

November 17 saw the award of the C-1 first stage industrial contract. Chrysler Corporation had been selected to build twenty S-1s for $200 million with deliveries effected in 1964-66. In anticipation of multi-stage C-1 flights the initial 10 development launches would be followed by a phase-in of the S-IVB in late 1964 and on 20 Dec. the Douglas Aircraft Company were contracted to develop this single J-2 stage.

One day later the Manned Space Flight Management Council decided that the C-5 would have a five J-2 second stage and virtually sealed the fate of the C-3 and C-4.

Saturn C-5 could become a development vehicle for Nova Direct Ascent lunar landings or, in the event that the Lunar Orbit Rendezvous mode was selected, be used alone for that purpose. Thus, through a lengthy and changeable evolutionary cycle. the future pattern of launch vehicle development for Apollo emerged. It was hoped that C-5 would be flying by 1965, eventually to be used in a dual launch for a possible Earth Orbit Rendezvous approach, if that mode was selected.

However, it is at this point that development of the C-5, later to be re-designated Saturn V, becomes irrelevant to the history of the C-1 and Saturn IB. Suffice it to have been shown in Part 1 to have had its origins within the C-1 stable. Part 2 of this article will continue the story of the C-1 and discuss the significance of the Saturn IB to past and present mission plans. A 3-part history of Saturn V appeared in *Spaceflight*, Jan. Feb. and Mar. 1971.

We shall continue our series on major launch systems with the final part of the Saturn V story and another episode in the evolution of the NASA Space Shuttle, which takes the history from October 1972 where the previous survey ended.–Ed.

SATELLITE DIGEST — 81

A monthly listing of all known artificial satellites and spacecraft, compiled by Robert D. Christy. Information is based on that supplied by the Space Department of the Royal Aircraft Establishment, Farnborough and other sources. For information on the derivation of orbital parameters, abbreviations, etc., see July 1972 issue, p. 262.

Continued from March issue, p. 115.

Name, designation	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclin-ation (deg)	Nodal period (min)	Launch centre, launch vehicle and payload/launch origin
Westar 2 1974-75A	1974 Oct 10.76 indefinite	Cylinder		35761	35770	0.0	1435.4	ETR Thor Delta WUTC/NASA (1)
Cosmos 687 1974-76A	1974 Oct 11.48 1 year			286	698	74.00	94.48	Plesetsk USSR/USSR
Ariel 5 1974-77A	1974 Oct 15.32 5 years	Cylinder 129	0.86 long 0.95 dia	504	549	2.88	94.96	Indian Ocean Scout UK/NASA (2)
Cosmos 688 1974-78A	1974 Oct 18.63 11.66 days (R) 1974 Oct 30.29	Sphere-cylinder 4000?	5 long? 2 dia?	179	349	62.82	89.77	Plesetsk USSR/USSR
1974-78D	1974 Oct 18.63 12.58 days 1974 Oct 31.21	Sphere?	2 dia?	145	294	62.81	88.88	Plesetsk USSR/USSR (3)
Cosmos 689 1974-79A	1974 Oct 18.94 1200 years	Cylinder?	1.3 long? 1.9 dia?	981	1017	82.94	105.12	Plesetsk USSR/USSR
Cosmos 690 1974-80A	1974 Oct 22.75 20.5 days (R) 1974 Nov 12.2	Sphere-cylinder? 5500?	6 long? 2.5 dia?	215	364	62.81	90.29	Plesetsk USSR/USSR (4)
Molniya-1AD 1974-81A	1974 Oct 24.53 5 years?	Cylinder-cone + 6 panels + 2 antennae 1000?	3.4 long 1.6 dia	656 646	40614 39715	62.82 62.84	736.37 717.87	Plesetsk USSR/USSR (5)
Cosmos 691 1974-82A	1974 Oct 25.40 11.86 days (R) 1974 Nov 6.26	Sphere-cylinder 4000?	5 long? 2 dia?	173	328	65.04	89.50	Tyuratam-Baikonur USSR/USSR
1974-82C	1974 Oct 25.40 16 days 1974 Nov 10	Sphere?	2 dia?	167	307	65.03	89.23	Tyuratam-Baikonur USSR/USSR
Meteor 19 1974-83A	1974 Oct 28.43 500 years	Cylinder + 2 vanes	5 long? 1.5 dia?	843	907	81.18	102.48	Plesetsk USSR/USSR
Luna 23 1974-84A	1974 Oct 28.60	Pyramid 4000?	3.1 high? 3.2 x 3.3 base	landed on Moon				Tyuratam-Baikonur USSR/USSR (6)
Luna 23 launch platform 1974-84B	1974 Oct 28.60 4 days 1974 Nov 1	irregular		183	246	51.54	88.72	Tyuratam-Baikonur USSR/USSR (6)
1974-85A	1974 Oct 29.81 4 months?	Cylinder 13300? (incl. fuel)	15 long 3.0 dia	162	271	96.69	88.86	WTR Titan 3D DoD/USAF
1974-85B	1974 Oct 29.81 6 years	Octagonal cylinder	0.3 long? 0.9 dia?	520	535	96.06	95.22	WTR Titan 3D DoD/USAF
1974-85C	1974 Oct 29.81 9 months			152	3795	96.98	126.59	WTR Titan 3D DoD/USAF

Name designation	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclin-ation (deg)	Nodal period (min)	Launch centre, launch vehicle and payload/launch origin
Intercosmos 12 1974-86A	1974 Oct 31.42 6 months	Octagonal ellipsoid 400?	1.8 long? 1.5 dia?	243	707	74.02	94.11	Plesetsk USSR/USSR (7)

Supplementary notes:

(1) Second US domestic communications satellite. Owned by the Western Union Telegraph Company and built by Hughes. Westar 1 was launched 1974 Apr 13.98 (1974-22A).

(2) British scientific satellite carrying five British and one American experiment designed to study X-ray emissions. The satellite was built by Marconi Space and Defence Systems.

(3) Ejected from 1974-78A during 1974 Oct 29.

(4) Satellite designed for biological research – carried laboratory animals and other biological specimens.

(5) Orbital data at 1974 Oct 25.6 and 1974 Oct 29.7.

(6) Lunar spacecraft intended to return a soil sample to Earth. Entered Lunar orbit 1974 Nov 1.91, completed approx. 50 lunar orbits before landing at 1974 Nov 6.23 near co-ordinates 13.5 deg N, 56.5 deg E. The soil scooping device was damaged on landing but the spacecraft continued a curtailed work programme until radio contact was broken on 1974 Nov 9.

(7) Socialist countries' co-operative satellite studying the atmosphere, the ionosphere and micro-meteorites. Onboard equipment was built in the USSR, the GDR, Bulgaria, Hungary, Roumania and Czechoslovakia.

Amendments and decays:

1973-41A, Cosmos 573, delete "2 panels" from shape.
1973-67A, Soyuz 12, delete "2 panels" from shape.
1974-10A, Cosmos 633 decayed 1974 Oct 4.48, lifetime 219.01 days.
1974-12A, Cosmos 634 decayed 1974 Oct 9.46, lifetime 217.79 days.
1974-36A, Cosmos 656, delete "2 wings" from shape.
1974-49A, Cosmos 664 was recovered 1974 Jul 11.34, lifetime 11.80 days.
1974-50A, Cosmos 665, add second orbit as follows: perigee is 703 km, apogee is 39660 km, inclination is 62.82 deg, period is 717.91 min.
1974-57D, add orbit as follows: perigee is 165 km, apogee is 255 km, inclination is 64.97 deg, period is 88.69 min.
1974-59G, decayed 1974 Aug 11.47, lifetime 16.18 days.
1974-60A, Molniya S 1, inclination of first orbit should read 47.49 deg. Add second orbit as follows: perigee is 35787 km, apogee is 35790 km, inclination is 0.07 deg, period is 1436.2 min.
1974-60B, decayed 1974 Aug 1.14, lifetime 2.64 days.

U.S. SPACELAB PAYLOAD

NASA's Office of Space Science has given the Marshall Space Flight Center overall responsibility for a definition study of the Atmospheric, Magnetospheric and Plasmas-in-Space (AMPS) Spacelab payload. The payload unit will be a spaceborne, Earth-orbiting scientific laboratory, manned by scientists and equipped to study the environment in which it flies. It is one of several Spacelab payloads planned for flight on the Space Shuttle during the 1980's and 1990's.

The Shuttle is the reusable launch vehicle now being developed by NASA as part of its future Space Transportation System. Spacelab, into which the laboratory unit will be installed for flight, is being designed by the European Space Research Organization (ESRO). It is a large basic module, carried in the capacious cargo bay of the Shuttle.

Through use of the laboratory, scientists expect to obtain a better understanding of the dynamic processes of the atmosphere and magnetosphere which influence every-day problems such as communications blackouts, atmospheric pollution and, possibly, even solar-weather relationships. Studies will also be made in the field of plasma physics in the zero gravity, free-space environment surrounding the Spacelab.

The laboratory unit experiments will involve both active and passive probing techniques. Missions flown to date have used primarily passive instrumentation which has simply measured the characteristics of these dynamic processes. With the use of active experiments such as electron accelerators and high-power transmitters, the payload unit will be able to momentarily perturb the atmosphere and magnetosphere and measure the resulting reactions. With its orbit in the ionosphere at an altitude of a few hundred kilometres, the Shuttle/Spacelab will be ideally placed to probe extensive regions of Earth's atmosphere and magnetosphere.

The ability to involve the scientist directly in the conduct of atmospheric and magnetospheric experiments will open a new dimension in space research. The laboratory will be available to scientists from large and small institutions.

Operation will be patterned after other national research facilities such as large ground-based telescopes. Scientists will be able to use the facility equipment furnished by NASA and have their own specialized equipment installed to personally conduct their experiments in space. They will work within the Spacelab or the orbiter cabin in a "shirtsleeve" environment, and control instruments which are externally mounted and exposed to the surrounding space. As many as four scientists will be able to work within the Spacelab payload unit on each mission.

During the definition study phase of the laboratory unit programme, Marshall Center will work closely with a science working group chosen last year by NASA. The group consists of 49 scientists from the United States, Canada, England, France, Germany, Italy, Norway, Sweden and Japan.

These scientists, who come from government, universities and industrial research laboratories, will advise the Marshall Center on payload scientific objectives and instrument requirements. Later this year, Marshall will initiate contracted studies for the design of the laboratory.

BOOK REVIEWS

Interstellar Communication: Scientific Perspectives
Ed. by Cyril Ponnamperuma and A. G. W. Cameron, Houghton Mifflin, 1974, pp. 226, £3.30.

This book provides a summary of the problems of CETI (communication with extraterrestrial intelligence) by ten workers, many of whom are well known in this field, having published within it from its beginnings as a recognised separate branch of study some fifteen years ago. It includes an abridged version of the Bibliography on Interstellar Communication that has recently also appeared in the 'Red Cover' issues of the JBIS. Pitched at undergraduate student level, it is conceptually advanced without having too much technical clutter and,as such,is probably ideal for those readers of Spaceflight wanting an introduction to this subject.

The book is based on a series of lectures organised at the NASA Ames Research Center in the summer of 1970. The lectures have been updated in subject matter and extensively re-edited into a uniform format for the book, but since it has been attempted to preserve some of the 'original vivacity' of the lectures, the dovetailing shows in several places. Perhaps the most extensive updating has been by Oliver for his chapter containing an excellent summary of the Cyclops study (for a radiotelescope system for detecting extraterrestrial intelligent life) and the technical arguments involved in its proposal.

The first six chapters of the book follow the outline which seems to be becoming *de rigueur* for discussions of this nature. This format requires an introduction, in this case the first chapter by Sagan, in which Drake's famous equation for the number of civilizations currently extant in the galaxy, i.e., $N = R_* f_p n_e f_l f_i f_c L$, is presented. There then follows a discussion on the problems of evaluating the parameters on the right hand side of this equation. This is done in the order that they appear above in the five following chapters by Cameron, Ponnamperuma, Arbib, McCarthy and Aronoff.

Following these are a pair of chapters on the real meat of the subject, i.e. how communication might be achieved. The subject of direct contact, albeit in the limited form of one-way probes, as introduced by Bracewell is apparently somewhat overwhelmed by the arguments set out against this by Drake in his discussion of radio communication. The abovementioned chapter by Oliver follows and the discussion is wound up by a summary and conclusion by Morrison which relates to the main text only in a general manner.

One small criticism that I would make is that most of the presentation seem heavily biased against the idea of direct physical interstellar travel, even to the extent of omitting that section relating to this topic from the bibliography. After all, if the expected contact does not happen (and who can say now what odds are to be placed on *that* eventuality), then after hundreds of years of first listening and then signalling fruitlessly, our (presumably by then) highly technologically competant civilization will be left with no other alternative than to go and find out why no one answered our call.

GERALD M. WEBB

The Next Ten Thousand Years
By Adrian Berry, Jonathan Cape, 1974, pp. 224, £2.50.

I like the spirit of this book. Optimism is something that we all need at the moment.

As may be expected from a competent journalist, the prose is, if not deathless, at least straightforward and easily readable. Unfortunately, the journalistic style used allows too many confusing adjectives, and the narrative to skirt the perils of looseness and omission that lead to error. For a representative example, consider the following three sentences. "If an object was released from an altitude of 300 miles, it would never hit the ground, although it would continue to 'fall' for the rest of eternity".

"But in the inner hole of Superspace, as we shall see, the journey would be much more rapid since there the ordinary laws of physics are altered."

(On Venus) "As the planet's surface absorbs the Sun's long infrared rays, it heats them up and re-radiates them." Now, I know what Mr. Berry is driving at (at least I think I do!) but would the readership at which the book is aimed? Although stimulating and entertaining to the well-informed, this book could be puzzling or misleading to its intended target, the ubiquitous 'intelligent layman'.

But leaving aside the odd tree or two, let us consider the forest as a whole. Between the introductory and concluding chapters in which the basic philosophical framework is set up, we are shown a vision of the breathtaking and unstoppable rise of technological man on and out across the Galaxy like some runaway mould in a culture dish. It's all here: lunar colonisation, terraforming planets, asteroid mining, F.T.L., Dyson spheres, laser sun-busters and so on. Great stuff! What a pity that, despite Mr. Berry's frequent assertions to the contrary, the inevitability of his scenario must remain in some doubt. Part of the reason for this can be gleaned from the book itself.

Chapter 1 pinpoints the start of this technological (and concomitant fiscal) uprush in growth with the formulation of the modern scientific viewpoint by Roger Bacon. It must be noted that this was a philosophical and *not* a technological advance and that further,such 'advances' quite outside Mr. Berry's cosmic scheme of things no doubt await us at unguessable intervals. In the next century, contemplating our ever-decreasing navels just might seem more meaningful than overcoming impending eco-drom by conquering the stars.

The final chapter tells of our good fortune that resources easily exploitable by primitive technologies were readily available when needed "in such abundance as almost to raise the suspicion of some cosmic design". This is unfortunate since,by chapter 2,Mr. Berry has already dismissed (in rather harsh terms) the ultimate fears of the 'limits to growth' school by arguing that given time, life on Earth could recover from any catastrophe such as nuclear war, no matter how severe. Now, leaving aside the question of whether it would be a worthwhile recovery if non-human life inhabited what remained, just *where* will be all of those easily exploitable resources that the new infant civilizations need to build their budding technologies? Nowhere! They will have all been used up by the first civilization to tread the road. It looks as though we have one chance only to make the grade and this is it. In this context it is depressing to note the apparent absence from the universe of detectable Kardashev type II and III civilisations.

But buy and read the book. £2.50 is very good value for the entertainment provided – a sustained roller-coaster ride of speculation. One final quibble re Appendix 1 in particular – will man *really* conquer the universe using imperial measure? Gad sir! The old queen would be pleased!

GERALD M. WEBB

Spaceflight

Spaceflight is published monthly for the members of the British Interplanetary Society.

Full particulars of membership may be obtained from the Executive Secretary at the Society's offices at 12, Bessborough Gardens, London, SW1V 2JJ: Tel: 01-828 9371.

Correspondence and manuscripts intended for publication should be addressed to the Editor at 12, Bessborough Gardens, London, SW1V 2JJ.

Opinions in signed articles are those of contributors, and do not necessarily reflect the views of the Editor or the Council of the British Interplanetary Society, unless such is expressly stated to be the case.

Members who would like to present papers to General Meetings, Main Meetings, or contribute to Space Study Meetings, are invited to write to the Executive Secretary, British Interplanetary Society, 12, Bessborough Gardens, London, SW1V 2JJ.

Space Study Meeting
Theme **THE VIKING PROGRAMME** by P. J. Parker.
To be held in the Kent Room, Caxton Hall, Caxton Street, London, S.W.1. on **4 April 1975**, 6.30-8.30 p.m.

Admission tickets are not required. Members may introduce guests.

Main Meeting
Theme **EUROPEAN PARTICIPATION IN EARTH RESOURCES (SPACE) PROJECTS**
To be held in the Large Physics Lecture Theatre, University College, Gower Place, London, W.C.1. on **9 April 1975** *(All day).*

Papers offered to date are as follows:-

1. Potential Applications of Space Image Analyses and the Development of Natural Resources, by Dr. D. Bannert.
2. Coordination of Remote Sensing Objectives, by S. R. Dauncey.
3. The Practical Use of Orbital Imagery for Resources Survey, by L. P. White.
4. EROS Mineral Exploration Results Applied to Future Programme Planning, by N. Press.
5. Satellite Monitoring of Atmospheric Gases, by Prof. A. R. Barringer and J. H. Davies.
6. Attitude Control of Earth Resources Rockets by an RF Interferometric Sensor, by Dr. G. Mayer.
7. The Use of Cluster Analysis for Generalisation of ERTS Data, by A. C. Armstrong.
8. Automation of Earth Resources Data Analysis, by O. E. Morgan and N. D. E. Custance.
9. Application of ERTS-1 Imagery to the Sudan Savanna Project, by C. W. Mitchell.
10. Contribution of ERTS-1 and Skylab Missions to Regional Studies in Italy, by A. M. Tonelli.
11. Telespazio Facilities for Acquisition and Processing of ERTS Data, by Ing. B. Ratti.
12. Automatic Cartography of ERTS Teledetection Data, by D. J. David, J. Deries and F. Verger.
13. Comparison of the Utility of Alternative Camera, Film & Filter Combinations for Space Photography from the Skylark Earth Resources Rocket, by Dr. J. R. Hardy.
14. Use of Photographic Imagery for Earth Resources Studies, by Dr. E. S. Owen-Jones.
15. *Film* Skylark over Argentina.

A copy of the Programme and Registration forms are available on request from the Executive Secretary.

Space Study Meeting
Theme **SATELLITE TRACKING** by Dr. D. G. King-Hele.
To be held in the Kent Room, Caxton Hall, Caxton Street, London, S.W.1. on **17 April 1975**, 6.30-8.00 p.m.

A general review of the radio and optical methods used in satellite tracking, their effectiveness and some of the results achieved.

Admission tickets are not required. Members may introduce guests.

Space Study Meeting
Title **A DEVELOPMENT STRATEGY FOR A EUROPEAN MINI-SHUTTLE** by D. Ashford
To be held in the Kent Room, Caxton Hall, Caxton Street, London, S.W.1. on **6 May 1975**, 6.30-8.00 p.m.

Admission tickets are not required. Members may introduce guests.

30th Annual General Meeting
The 30th Annual General Meeting of the Society will be held in the Kent Room, Caxton Hall, Caxton Street, London, S.W.1. on **27 June 1975**, at 6.30 p.m. A detailed Agenda appears on page 154 of the April issue of *Spaceflight.*

Nominations are invited for election to the Council. Forms can be obtained from the Executive Secretary. These should be completed, signed and returned not later than **16 May 1975.**

Should the number of nominations exceed the number of vacancies, election will be by postal ballot. Voting papers will then be prepared and circulated to all members before the date of the meeting.

26th IAF Congress
To be held in Lisbon (Portugal), from **21-27 September 1975.** The theme will be 'Space & Energy'.

Main Meeting
Theme **COMPUTER TECHNIQUES IN SPACE PROJECTS**
To be held in the Large Physics Theatre, University College, Gower Place, London, W.C.1. on **24 September 1975** *(All day).*

Offers of papers are invited. Further details are available from the Executive Secretary.

Lecture
Title **THE ATMOSPHERES OF JUPITER AND ITS MOONS** by Dr. G. E. Hunt.
To be held in the Small Physics Theatre, University College, Gower Place, London, W.C.1. on **25 September 1975**, 6.30-8.30 p.m.

Admission tickets are not required. Members may introduce guests.

Main Meeting
Theme **AERONAUTICAL AND MARITIME SATELLITES**
To be held in the Large Physics Theatre, University College, Gower Place, London, W.C.1. on **25 September 1975** *(All day).*

Offers of papers are invited. Further details are available from the Executive Secretary.

Short Film Evening
A Programme of short (10-15 min.) films not previously screened by the Society will take place in the Botany Lecture Theatre, University College, Gower Street, London, W.C.1. on **29 October 1975**, 6.30-8.30 p.m.

Admission tickets are not required. Members may introduce guests.

Lecture
Title **DIRECT SPACE PROBE INVESTIGATIONS OF COMETS** by Dr. D. W. Hughes.
To be held in the Lecture Theatre, Royal Society of Arts, John Adam Street, Strand, London, W.C.2. on **7 November 1975**, 6.30-8.30 p.m.

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SPACEFLIGHT

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Kenneth W. Gatland, FRAS, FBIS

Assistant Editor:
L. J. Carter, ACIS, FBIS

CONTENTS

MILESTONES

February

20 Atlas-Centaur carrying seventh Intelsat 4 communications satellite malfunctions and is destroyed some 400 sec. after lift-off from Kennedy Space Center, Florida. Satellite was meant to provide back-up capability to existing satellites (Intelsat 3 and 4) in geo-stationary orbit above Indian Ocean.

24 Japan launches 190 lb. (86 kg) solar radiation and thermospheric structure satellite by Mu-3C rocket from Kagoshima Space Centre, Kyushu island. Orbit: 249 km x 3,129 km x 31.54 deg. inclination.

28 Soviet ASTP group of cosmonauts and specialists leave Johnson Space Center, Houston, after completing extensive training session with U.S. personnel. Disclosed that the six U.S. prime and backup ASTP astronauts and support crews, during final joint training session at Star Town in April-May, will be flown to Tyuratam cosmodrome about 27 April to inspect preparations for 15 July mission. U.S. ASTP officials including George M. Low, NASA deputy administrator, expected to visit cosmodrome about 19 May.

28 Soviets launch eight satellites – Cosmos 711-718 – from single carrier rocket into orbits ranging between 1,449 and 1,530 km inclined at 74 deg to equator, probably for purposes of defence communications.

March

4 By mid-day (Moscow time) Salyut 4 has made 1,077 revolutions of the Earth. Orbit is 331-358 km inclined at 51.6 deg to equator; period 99.2 min. On-board systems continue to function smoothly.

10 First Soviet Conference on Space Studies of Earth opens in Moscow explaining how photographs obtained from Soyuz and Salyut helped to "identify previously unknown peculiarities of the tectonic pattern of various geological structures." Some data already processed provides a guideline to geologists in prospecting for new oil and gas deposits; photo-surveying from Soyuz 9 showed distribution of salt deposits in area of the Kara-Bogaz-Gol Bay in detail. A "scientific-methological" centre on the study of the Earth from outer space is being established.

12 ESRO awards British Aircraft Corporation £67,000 contract to define ways in which natural microwave radiation from the Earth's surface can be used to collect data on the world's oceans, polar ice caps and land regions; also to collect meteorological data and monitor pollution in upper atmosphere. Data to be used in the design of future European satellite PAMIRASAT (Passive Microwave Radiometer Satellite). BAC to cooperate with microwave radiometer specialists from Bristol University, Appleton Laboratory of SRC, Technical University of Denmark and with oceanographers in Denmark and Sweden.

15 German space probe Helios 1 flies within 28 million miles (45 million km) of the Sun at 5.13 a.m. EDT.

16 Mariner 10, making third approach to Mercury, flies within 199 miles (320 km) of crater-pocked surface at 6.40 p.m. EDT, returning more photos and data.

ASTP FLIGHT HARDWARE

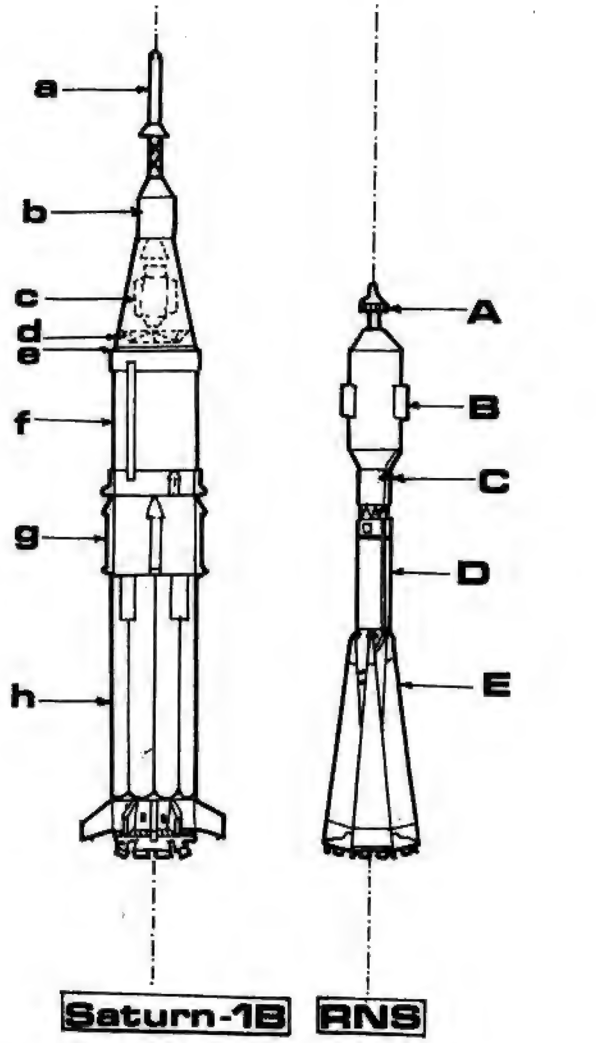
On 15 July the United States and the Soviet Union are due to begin their first collaborative experiment in manned spaceflight – the link up of an Apollo CSM with a Soyuz some 140 miles (225 km) above the Earth. The drawings on these pages were produced by Robert Edgar from material supplied by NASA and Rockwell International. They supplement information given in the article "A Meeting in Space" published in our issue of January 1975.

Below is the proposed Events Schedule which may be subject to change:

ASTP Major Events (Provisional).

Day/Date (1975)	Event	GET	GMT	EDT
Tues. 7/15	Soyuz Launch	**00:00**	12:20	08:20 AM
Tues. 7/15	Apollo Launch	**07:30**	19:50	03:50 PM
Tues. 7/15	Apollo TD & E	**08:53**	21:13	05:13 PM
Tues. 7/15	NC1	**13:12**	01:32	09:32 PM
Tues. 7/15	NPC	**13:56**	02:16	10:16 PM
Wed. 7/16	Docking Module Checkout	**26:00**	14:20	10:20 AM
Thurs. 7/17	NC2	**48:34**	12:54	08:54 AM
Thurs. 7/17	Rendezvous (TP1)	**50:54**	15:14	11:14 AM
Thurs. 7/17	Station Keeping	**51:28**	15:48	11:48 AM
Thurs. 7/17	Docking Approach	**51:50**	16:10	12:10 PM
Thurs. 7/17	Docking	**51:55**	16:15	12:15 PM
Thurs. 7/17	1st Transfer Activities Begin	**52:42**	18:02	01:02 PM
Thurs. 7/17	Docking Module-Soyuz Hatches Open	**55:03**	19:23	03:23 PM
Thurs. 7/17	1st Transfer Ends	**58:06**	22:26	06:26 PM
Fri. 7/18	2nd Transfer Begins	**68:39**	08:59	04:59 AM
Fri. 7/18	2nd Transfer Ends 3rd Transfer Begins	**74:48**	15:08	11:08 AM
Fri. 7/18	3rd Transfer Ends 4th Transfer Begins	**78:46**	19:06	03:06 PM
Fri. 7/18	4th Transfer Ends	**81:50**	22:10	06:10 PM
Sat. 7/19	Undock	**95:42**	12:02	08:02 AM
Sat. 7/19	Station Keeping	**95:50**	12:10	08:10 AM
Sat. 7/19	Contact	**96:08**	12:28	08:28 AM
Sat. 7/19	Dock	**96:20**	12:40	08:40 AM
Sat. 7/19	Undock	**98:39**	14:59	10:59 AM
Sat. 7/19	Separation	**106:34**	22:54	06:54 PM
Mon. 7/21	Soyuz Landing	**142:30**	10:50	06:50 AM
Thurs. 7/24	Apollo Landing [1]	**224:59**	21:19	05:19 PM

1. Tentative.

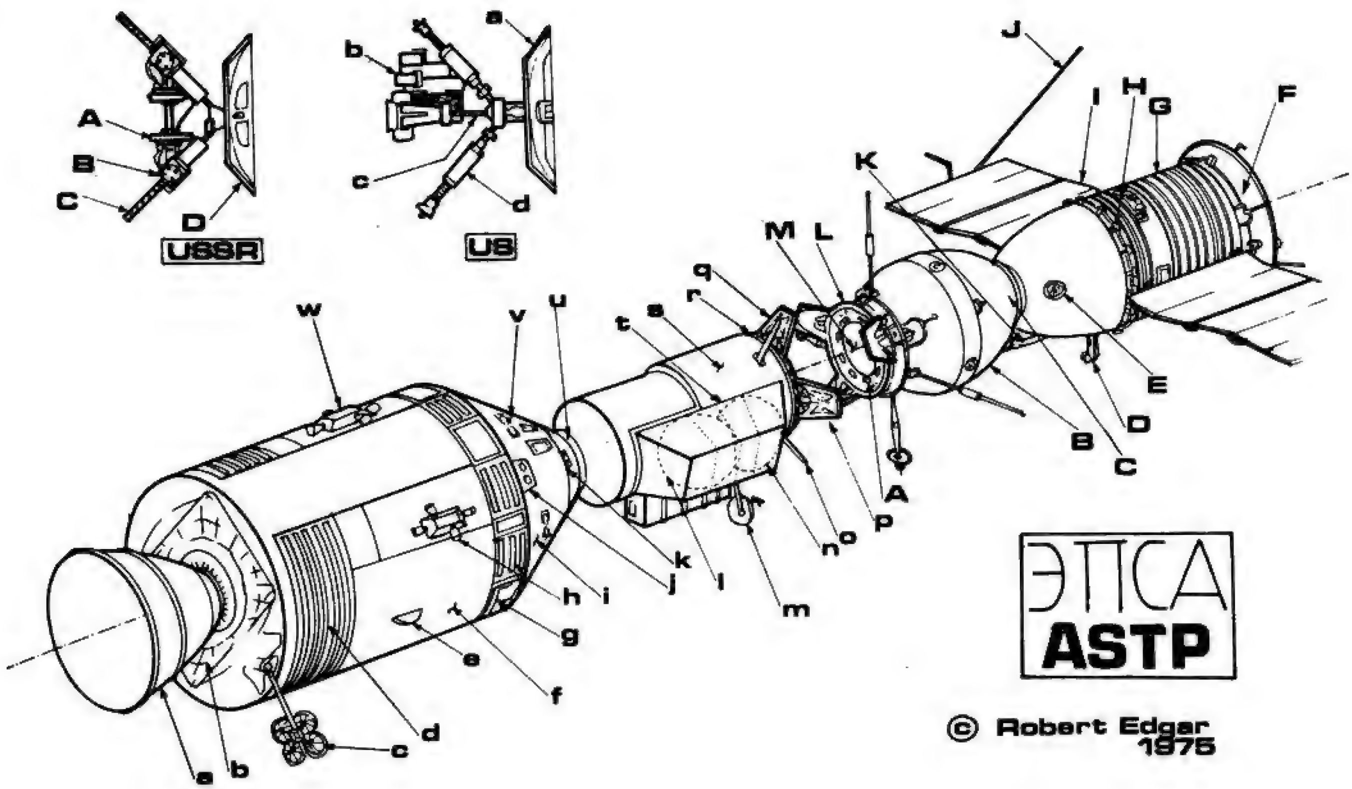


ASTP FLIGHT HARDWARE

These drawings depict the basic flight hardware for the Apollo Soyuz Test Project scheduled to begin on 15 July.

Saturn IB
a Launch Escape System.
b CSM (Command Service Modules).
c DM (Docking Module).
d DM support structure.
e Instrument Unit (controls powered flight & vehicle environment).
f SIV-B stage (22 x 29 ft., 1 J-2 engine, 230,000 lb. thrust).
g Interstage.
h SI-B stage (21.5 x 80 ft., 8 H-1, total 1,640,000 lb.).
Total height 224 ft., weight 1,297,000 lb.

RNS (Rakyeta Nosityel Soyuz)
A Launch Escape Tower.
B Soyuz aerodynamic shroud.
C Second stage (4 engines).
D First (core) stage (RD-108 engine cluster, approximately 100 ton thrust).
E Strap-on booster for first stage (RD-107 engine for each, approximately 100 ton thrust).
Total height approximately 158 ft.



CSM/DM

a Service Propulsion System expansion nozzle.
b SM heat shield.
c Steerable, high-gain S-band antenna.
d Environmental Control System radiator.
e Scimitar antenna.
f Service Module.
g Doppler receiver antenna.
h RCS quad A.
i Command Module.
j CM pitch jets.
k CM forward pitch jets.
l Oxygen tank.
m Docking target.
n Nitrogen tank.
o VHF antenna.
p US docking system.
q Docking guide.
r Structural ring.
s Docking Module.
t Tank Cover.
u CM/DM docking probe/drogue.
v CM roll jets.
w RCS quad D.

Soyuz

A Capture latch
B Orbital Module (main work, rest and experiments compartment).
C Orbital Module/Descent Module tunnel, surrounded by parachute systems.
D Periscope sight for docking target.
E Descent Module porthole.
F Propulsion system.
G Instrument Module (SM equivalent).
H 'T' telemetry antenna.
I Solar panel.
J Main downlink antenna.
K Intermodule umbilical.
L Structural ring.
M Soviet Docking system.

Docking Systems

The Soviet and American docking units, while being mutually compatible and compatible with themselves, differ in the mechanism used for extending and retracting the structural ring. The US system, shown retracted in the large drawing, uses spring-loaded actuators to extend it into the active position and a motor-driven cable system to retract it back to the passive position. The USSR uses a motor-driven screw (shown in the extended position in the large drawing but retracted in the enlargement) both ways.

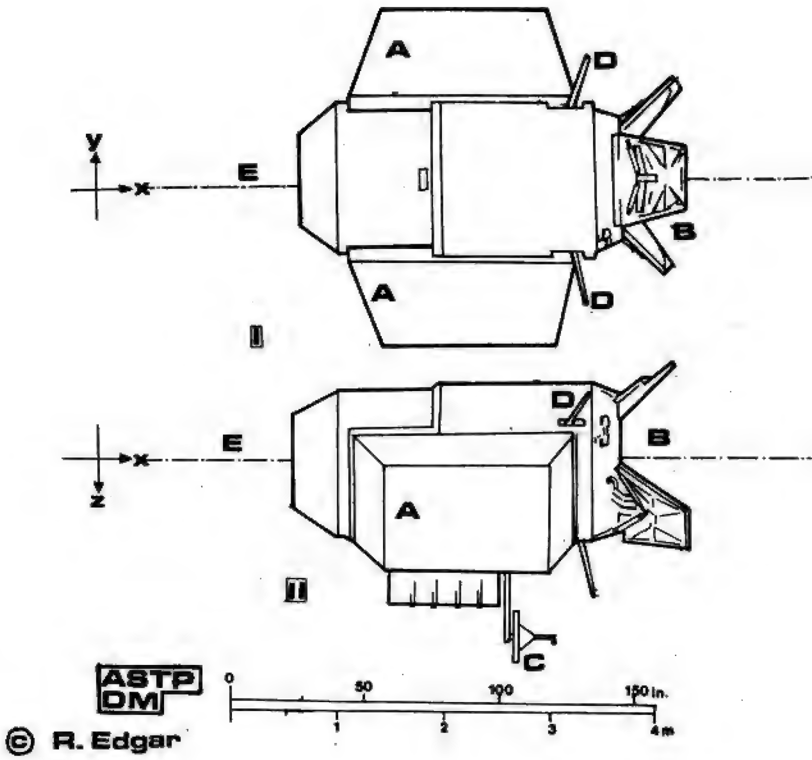
US

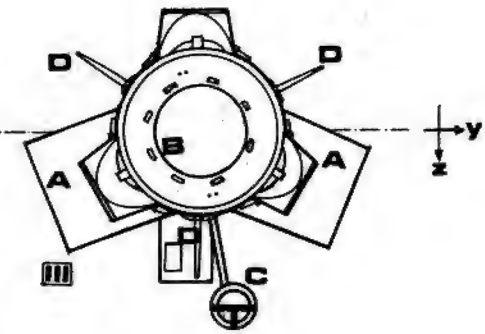
a Docking guide (see CSM/DM q).
b Motor to wind in cable.
c Cable.
d Actuator.

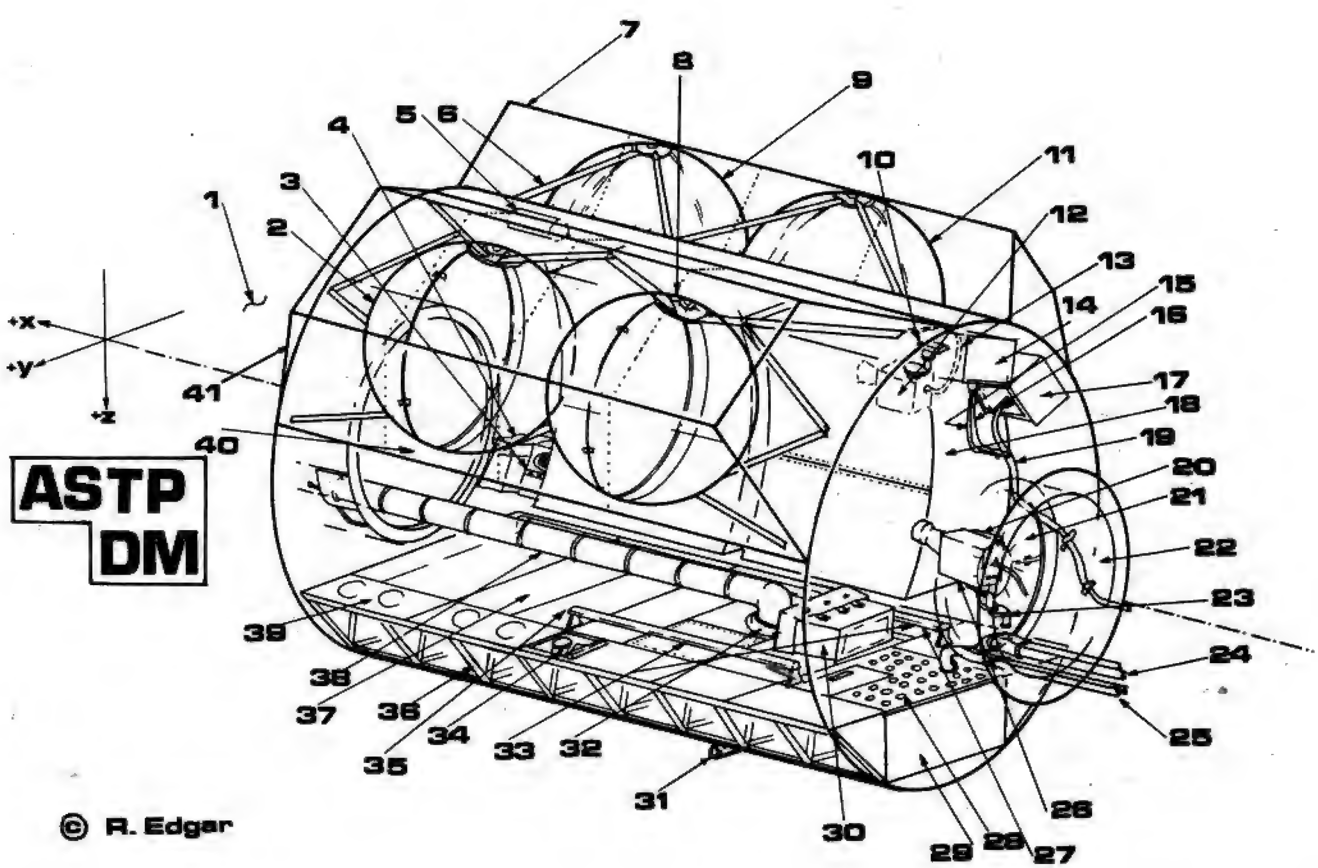
USSR

A Attachment to Structural Ring.
B Motor.
C Threaded screw.
D Docking guide (see Soyuz M).

Docking Module: Dimensions 3.15 x 1.42 m (main cylinder). DS maximum width 2.032 m; docking guides inclined at 45 deg. Extension of ring is 0.3048 m when in active position.







Docking Module

I plan view looking in the plus z direction;
II side elevation looking in the pluz y direction;
III end elevation looking towards the Docking System in the minus x direction.

A Tank cover.
B Docking system.
C Docking target.
D VHF antenna.
E Position of CM after T & D.

Apollo Soyuz Test Project: Docking Module (DM)

The DM is the essential connecting link between the Apollo spacecraft, with its 5 p.s.i. atmosphere, and the Soyuz with a 10 p.s.i. atmosphere. It was designed and built relatively quickly and cheaply, with the large weight margin allowed by the Saturn 1B launch vehicle. Its basic structure was fabricated from thick aluminium plate rather than the honeycomb structure more normally employed.

1. Position of the Docking System.
2. Pressurised Nitrogen (N_2) tank.
3. Communications speaker box.
4. Oxygen masks and hose container.
5. Fire extinguisher.
6. Tank support strut.
7. Tank cover (-y).
8. Pressurised Oxygen (O_2) tank.
9. N_2 tank.
10. TV camera bracket.
11. O_2 tank.
12. TV camera alternative location.
13. Camera cable alternative routing.
14. Panel 861 – Soviet J-box.
15. USSR TV cable.
16. COU cable (Soviet J-box).
17. Panel 862 – Scientific J-box.
18. Storage.
19. UV drag-through umbilical routed from Command Module.
20. TV camera monitor (small screen mounted on camera).
21. Hatch.
22. Command Module docking port – Tunnel No. 1.
23. TV camera bracket.
24. O_2 umbilical (CTR) from Command Module.
25. O_2 umbilical (LH) from Command Module.
26. TV camera.
27. Long handhold.
28. Ventilation fan inlet.
29. Equipment Module.
30. Flight data file.
31. Non-propulsive vent.
32. Ventilation fan outlet.
33. Handholds.
34. Panel 821 – DM total pressure gauge; relief valve.
35. Control panel for O_2 and N_2.
36. Equipment module support structure.
37. Controls and displays (atmosphere, O_2 masks).
38. Ventilation duct.
39. Tunnel No. 2 vent valves.
40. Soyuz docking port – Tunnel No. 2.
41. Tank cover (+y).

ASTP Spacecraft Colour Scheme

Command Module, Docking System – High-gloss silver.
Service Module skin – non-gloss silver.
Reaction control system panels, ECS radiator – non-gloss white.
SM heat shield – glossy light grey.
SPS engine fairing and RCS nozzles – Semi-gloss gold.
SPS nozzle – semi-gloss dark blue-grey.
Soyuz main body – non-gloss light blue-green.
Soyuz solar panels – high gloss dark blue.
DM S-band antenna – non-gloss black.

With preparations for the ASTP mission reaching a climax the U.S. prime and back-up astronauts were due to complete their joint training with Soviet colleagues at Star Town near Moscow in April and May. After the cosmonauts' visit to the Kennedy Space Center in February, the astronauts are to pay a two-day visit to the Tyuratam cosmosdrome in central Asia about 27 April. A party of 8-10 U.S. technicians are expected at Tyuratam around 12-19 May for electromagnetic and other radio-related testing with the Soyuz spacecraft.

GLOBAL MAP

Map makers of the Soviet Union and Eastern Europe have completed the first ever global "portrait" of the Earth. Experts in geodesy joined catographers of Bulgaria, Hungary, the German Democratic Republic, Poland, Rumania, Czechoslovakia and the USSR in producing the map which consists of 234 sheets, 115 of them made by Soviet cartographers.

The scale of the map is 1:2,500,000. It is the first time that the entire planet has been mapped to the same scale in metric measurement incorporating a standard system of symbols.

UK POLLUTION PROBE IN NIMBUS G

The only British experiment to fly in the NASA Nimbus G weather satellite in late 1978 will be supplied by Hawker Siddeley Dynamics under a contract worth £250,000 from Oxford University acting on behalf of the Science Research Council. The instrument is a radiometer designed to investigate the Earth's upper atmosphere.

The experiment was devised by Dr. J. T. Houton, FRS, of the Department of Atmospheric Physics, Oxford University, and during all stages of development HSD's Space Division at Stevenage, will work in close collaboration with the University and Rutherford Laboratory. Designed to operate in the infrared bands between wavelengths of 2.7 and 100 microns, the radiometer will examine the atmospheric structure in this largely unexplored region and also measure the mixing ratios of a number of selected gases between the altitudes of 30 and 130 km. Thus the degree of atmospheric pollution by the selected gases may be determined. The polar orbit of the satellite will enable the instrument to carry out a continuous examination of the atmosphere on a global basis.

The demanding requirements of the design, say HSD, will involve the use of the most advanced technology in optics and electronics.

[Continued on page 188

T 6

PROJECT HELIOS

By Mike Howard

Introduction

As other spacecraft probe the outer reaches of the Solar System so a new breed of craft begins to take a closer look at the centre of that system. Twenty-eight million miles from the Sun where the temperature would melt lead is the target for the joint West German-United States Helios spacecraft.

As long ago as September 1966 President of the United States Lyndon B. Johnson and Chancellor Ludwig Erhard of the Federal Republic of Germany laid the groundwork for Helios when they agreed that their two countries should work together on a major space project. Such a venture, while following NASA's foreign cooperation policy, would greatly improve the status of German space technology. The following year, more discussions took place between NASA and the Bundesministerium für Forschung und Technologie (BMFT) (Ministry for Research and Technology) leading to the mission definition phase from July 1968 to April 1969.

In June 1969 Project Helios was officially born. The Memorandum of Understanding required that Germany develop the spacecraft while the United States provide the launch vehicle and launch facilities. Each of two Helios probes were to carry both American and German experiments. The United States also undertook to act as technical advisor and provide training when and where necessary.

Since September 1969 joint working group meetings have taken place at approximately six monthly intervals alternately in the U.S. and Germany. The last meeting, prior to launch of the first spacecraft, at the Jet Propulsion Laboratory in Pasadena from 15 to 21 May 1974, was held to complete mission plans.

Objectives and Experiments

Each of the Helios solar probes has 10 scientific experiments the main objectives of which are the exploration and study of interplanetary space in the vicinity of the Sun:

(a) To study the spatial gradient of the interplanetary medium by measuring the magnetic field, the density, temperatures, velocity and direction of the solar wind, i.e., electrons, protons and alpha particles;

(b) To study discontinuities and shocks in the interplanetary medium magnetically, electrically and by observing the behaviour of the solar wind particles;

(c) To study radio waves and in situ the electron plasma oscillations believed responsible for Type III radio bursts and other wave-particle interactions;

(d) To study the propagation of solar cosmic rays and to a certain degree their spectral composition;

(e) To measure the spatial gradient of galactic cosmic rays, to separate the solar and galactic components of the low energy cosmic ray flux especially with respect to protons and electrons;

(f) To study the spatial gradient and dynamics of the interplanetary dust and chemical composition of dust grains by observing the zodiacal light and by counting and analysing individual dust particles;

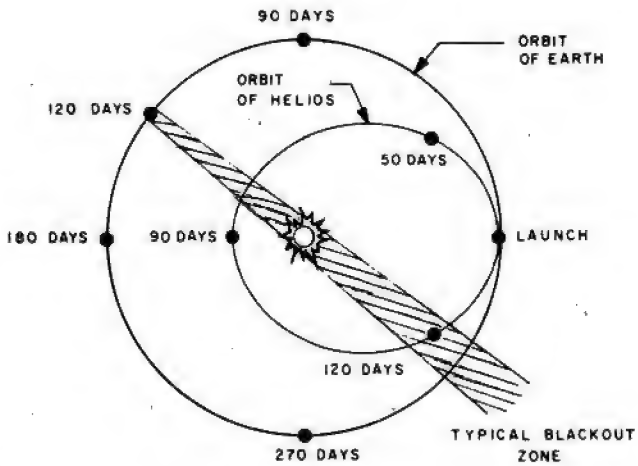


Fig. 1. Helios in relation to Earth's orbit.

National Aeronautics and Space Administration

(g) To X-ray monitor the solar disk by means of a Geiger-Muller counter. This device will enable the experiments to monitor the far side of the Sun from orbit regions remote from the Earth;

(h) To test the theory of general relatively with respect to both orbital and signal propagation effects

Determine the dynamical oblateness of the Sun
Determine the quadrupole mass distribution of the Sun
Improvement of the ephemerides of the inner planets and the Moon.

Of the 10 experiments carried, three are supplied by the United States, seven by Germany:

1. *Plasma Experiment.* Measurement of low energy charged particles (solar wind);
2. *Flux Gate Magnetometer.* Measurement of the interplanetary quasistatic magnetic field (0 to 4.7 Hz), and shock waves, and the interplanetary magnetic field;
3. *Search Coil Magnetometer.* Measurement of field fluctuations and shock wave forms (5 Hz to 3 KHz);
4. *Plasma and Radio Wave Experiment.* Measurement of radio waves (50 Hz to 2 MHz) and plasma (10 Hz to 100 KHz);
5. *Cosmic Ray Experiment.* Measurement of protons, alpha particles, heavier nuclei of solar and galactic origin, and medium and high energy particles, and X-rays;
6. *Electron Detector.* Measurement of medium energy electrons, protons, and positrons;
7. *Zodiacal Light Photometer.* Measurement of zodiacal light and wave length and energy of interplanetary dust particles;

8. *Micrometeoroid Analyser.* Measurement of dust particles, mass and energy of interplanetary dust particles;
9. *Celestial Mechanics Experiment.* Measurement of orbit parameters to test general relativity theories; and
10. *Faraday Rotation Experiment.*

To date two spacecraft, Pioneers 10 and 11, have shown conclusively that the solar magnetic field spirals out beyond Jupiter, a distance of 5 astronomical units*. This field and the solar plasma responsible for drawing it out form a "boundary" between our Solar System and the rest of the Galaxy which blocks the entry of all but relatively high energy particles from other parts of the Universe.

Commenting on the Helios missions Goddard Space Flight Center's Helios Project Scientist, Dr. James H. Trainor said: "Helios will not only take our instruments in closer to the Sun than Man has ever been able to go, it will provide scientific observations of activity on the back side of the Sun as seen from Earth. This hidden activity may well be responsible for interplanetary effects seen near Earth.

Additionally Helios will be occulted by the Sun at fairly close distances to the Sun, allowing fine measurements in the fields of relatively, celestial mechanics and density measurements in the high altitude solar atmosphere." Instrumentation of the type carried aboard Helios is also to be found on two Interplanetary Monitoring Platforms (Explorers 47 and 50), Pioneer spacecraft in a heliocentric orbit at about one AU, and on Pioneers 10 and 11 in the outer Solar System. Correlation of solar data from these spacecraft operating in widely varying parts of our Solar System and that received from Helios will be of great scientific interest during this project.

Spacecraft

The Helios spacecraft will be in an elliptical orbit ranging from one AU to 0.3 AU with a period of 180 days (Fig. 1). Each has a design lifetime of 18 months, although the missions will be considered successful after the first perihelion pass some 100 days after liftoff. Helios B may be directed slightly closer to the Sun at 0.28 AU.

The spacecraft consists of a short 16-sided cylindrical body with a diameter of 5.7 ft. (1.75 m), and two conical solar arrays attached at each end giving the probe a spool shape (Fig. 2). At the widest point of the arrays the craft measures 9.1 ft. (2.77 m) in diameter. Eight radial equipment platforms sandwiched between two circular equipment platforms make up the central body of the craft. Most of the on-board equipment and experiments are mounted within the body on the radial platforms. Notable exceptions are the magnetometer experiments which are mounted on two deployable double-hinged booms situated diametrically opposite to the central body. Two other diametrically opposite booms attached to the cylindrical body serve as antennae for the radio wave experiment. When both antennae are fully deployed they measure 105 ft. (32 m) from tip to tip.

Below the central body is a circular adapter which mates the spacecraft to the launch vehicle and through the centre of which several long telescopes look out of the body's

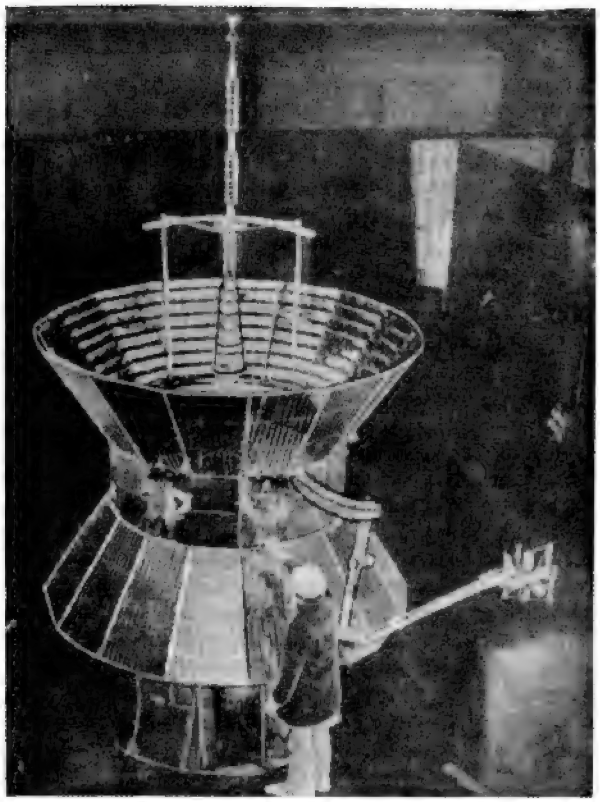


Fig. 2. Helios spacecraft.

Messerschmitt-Bolkow-Blohm

lower platform. The telecommunications antenna system projects above the upper solar array. This comprises three antennae attached one above the other. At the lower level is a narrow beam high-gain antenna (23 db) with a mechanically despun reflector, above that is the medium-gain antenna (toroidal pattern, 7 db), and finally at the top of the antenna mast is the low-gain antenna. Including solar arrays Helios stands 7 ft. (2.12 m) tall; overall height including antenna mast is 13.7 ft. (4.20 m). Height of the central compartment is 1.8 ft. (0.55 m). Launch weight is 815 lb. (370 kg) of which experiments account for 158 lb. (72 kg).

Power Subsystem

The Helios power subsystem is composed of solar panels, batteries, and regulators.

Mounted on the conical surfaces at each end of the probe's central body, solar cells have the task of providing the craft's power requirements as soon as it enters Earth orbit after launch. Between the cells are interspersed second-surface mirrors to radiate excess heat thus providing a means of achieving tolerable temperatures on the solar array. Power output from the panels is a minimum of 240 W at aphelion and increases greatly towards perihelion at which time the temperature of the cells should reach a maximum of 165°C.

From five minutes before liftoff until the solar arrays become active the batteries supply all power requirements aboard the spacecraft. Additionally the 8.0 Ah battery is used to activate pyrotechnic devices such as are installed

* *1 astronomical unit (AU) is 93 million miles (149.7 million km) from the Sun.*

for boom deployment. A silver-zinc type battery can provide 20-30 watt-hours/lb. Voltage on the battery is monitored by ground control stations and, if necessary, can be disconnected or reconnected to the main bus on command.

Regulation of the power subsystem is provided at 28 volts +2 per cent by the regulated bus technique. This method provides reliability through circuit simplicity, low component power dissipation, and predictable electrical interface characteristics.

Thermal Control Subsystem

Since Helios passes closer to the Sun than any previous spacecraft the project presented a major challenge in the field of thermal control. This involved a demanding series of tests at the Jet Propulsion Laboratory during which the despun reflector temperatures were raised to 700°F (370°C) for about 10 days to simulate the maximum temperature that the spacecraft was likely to encounter at 0.3 AU. The radiation level survived was equivalent to 11 times the solar intensity experienced at the edge of the Earth's atmosphere.

Thermal control aboard the probe is both active and passive. Within the central body the experiments and equipment are so arranged that they will dissipate heat as independently as possible, while second-surface mirrors over several layers of insulation cover the outer wall of the central compartment. Louvres on the top and bottom of the body section allow heat from the central compartment to be radiated to space in an axial direction. A shield system around the louvres prevents heating of the inner surfaces of the solar arrays. Second-surface mirrors also cover 50 per cent of the solar panels to re-radiate any excess heat to space. Heaters are available to provide active thermal control should passive methods allow too great a reduction in temperature. In addition the spacecraft revolves once per second to ensure even distribution of solar heat on its surfaces.

The thermal control subsystem was expected to maintain a temperature range of between 14°F (-10°C) and 86°F (+30°C) within the experiment areas. A dry lubricant in the bearing system of the high-gain antenna reflector will withstand the full range of expected temperatures while parts of the reflector itself will survive temperatures of 932°F (500°C).

Attitude Control Subsystem

The Helios spin rate of 60 r.p.m. is adjusted and maintained by the attitude control subsystem. This system also controls spacecraft attitude, despin and alignment of the high-gain antenna, and provides Sun reference pulses to the experiments.

To effect the required spacecraft attitude the subsystem uses sensing systems that reference the Sun and stars, a propulsion system, and damper.

Despin of the high-gain antenna reflector is effected by a direct current stepper motor in order that it remains stationary with respect to the spacecraft-Sun line. The angle can be commanded to re-align to point Earthward.

Communications

Communication between Helios and Earth is possible during the entire mission, except for periods when the spacecraft passes behind or in front of the Sun at which time solar noise will drown the probe's signal. During such times, data will be stored for transmission at a later opportunity.

The Deep Space Network (DSN) provides 85 ft, (26 m) antennae coverage for most of the Helios missions and it is with this in mind that the spacecraft telecommunications subsystem was designed. However, at other times the 325 ft. (100 m) German Effelsberg antenna and the 210 ft. (64 m) DSN antennae may be available and therefore the subsystem was made flexible enough to take advantage of the greater data rates possible with these stations.

The communications system (RF subsystem) transmits scientific and technical data from the spacecraft subsystems and experiments to the ground as well as receiving and passing on commands destined for equipment on board the craft. All three antennae may be used at three selectable power levels for spacecraft to Earth transmission. Should a failure occur in the despin mechanism of the high-gain antenna the medium-gain will be used. A maximum down-link data rate of 4096 bits per second can be achieved when the high-gain antenna is used in conjunction with the high power amplifier.

Under normal operational circumstances, data from the experiments and other spacecraft "housekeeping" is transmitted directly to Earth after being merged and formatted in the data encoder. A storage capacity of 500 kilobits of core memory is available to record high resolution data from the magnetometers and plasma experiments during periods of magnetoplasmadynamic shock. This core is also utilized when direct Earth communication is not possible. At such times the data is recorded and transmitted as soon as practicable.

Determination of orbit parameters and predictions for tracking are made by two-way doppler measurements and the measured direction of arriving signals. In order that this be done, coherent transponder operation is selected by telecommand. This permits the transmitted down-link frequency to be coherently derived from the received up-link frequency allowing a high degree of accuracy in two-way doppler measurements.

As part of the celestial mechanics experiments, the Deep Space Network will transmit a pseudo-random range code. This code will be detected by Helios and remodulated on the down-link, allowing range measurements to be made with an overall ranging signal uncertainty of less than 100 nanoseconds (one tenth of one million of a second).

Tracking and Data Acquisition

Tracking and Data Acquisition for Project Helios is accomplished through the Deep Space Network and the German communications system, command station, and data centre. The NASCOM station at Madrid is the switching centre for the data interfaces between the DSN and German Control Centre (GCC). All necessary data links between its stations and Madrid are supplied by NASA while the German Bundespost provides the equipment and lines between Madrid and the GCC for telemetry and high speed data. Control of the DSN is exercised from the Space Flight Operations Facility (SFOF) in Pasadena, California, at all times although Germany has overall mission control. During the first three weeks of each mission a German team at JPL controls the flight, where upon control switches to the German Space Operations Centre in Oberpfaffenhofen near Munich.

Telecommunication between Earth and spacecraft employs the DSN unified S-band system. The spacecraft's single coherent up- and down-link carrier is modulated with ranging or command on the up-link and ranging and telemetry on the down-link.

The DSN undertook to provide three 26 metre antennae

(Goldstone, Madrid, Canberra) 24 hours per day from launch to first solar occultation after which DSN coverage will be on a shared basis in competition with other projects. During first perihelion the 210 ft. (64 m) network will be available on a priority basis (at other times it is available on a competing basis). The German Effelsberg station near Bonn is available for telemetry reception only, four hours per day, all-year round.

Data recorded on magnetic tapes at the telemetry ground stations or control centres are mailed to the German Data Centre and the Goddard Space Flight Center (GSFC) for processing. Data obtained at remote DSN stations are forwarded to JPL in real time for rapid processing, the processed result being provided to both the GSFC and the German Control Centre on duplicate master data records (MDR). From the MDR are prepared individual experiment data records (EDR) for distribution to each experimenter within 30 days. The GCC provides a similar service with scientific data received at the Effelsberg station. Engineering data is sent to the German Control Centre in real time to provide the information necessary for spacecraft control.

Launch Vehicle and Facilities

The Titan III-E/Centaur [1] is the launch vehicle for both Helios missions.

The Titan IIIE booster comprises a two stage liquid propellent core vehicle and two strap-on solid rocket motors (SRM). Two tenths of a second after ignition of the SRM's liftoff occurs followed at 6.5 seconds into the flight by the execution of a programmed roll manoeuvre effected by the Titan's thrust vector system deflecting the SRM's rocket exhaust gasses. As soon as acceleration reduces to 1.5 g Stage I ignition of the Titan occurs followed 12 seconds later by jettisoning of the solids. Stage I continues firing to propellent depletion at T plus 260 seconds at which time Titan Stage II ignition occurs. One second later separation takes place.

All attitude control during Stage I and Stage II phases is commanded by the Centaur guidance system and controlled by the Titan flight control system. One minute after Stage II ignition the payload shroud is jettisoned. When acceleration reduces to 0.012 g upon propellent depletion (467 seconds after launch) the Centaur commands separation. A pyrotechnic charge severs the Centaur interstage adapter and retrorockets brake the spent Titan Stage II clear of the remaining stages. Ten and a half seconds after separation the Centaur main engine is started and continues to fire until the planned parking orbit is achieved. After a period of coasting a second Centaur burn of approximately 273 seconds occurs.

For the Helios missions an additional fourth stage package is necessary, this is the Delta or TE-M-364-4 stage. This stage comprises a spin table, TE-M-364-4 solid propellent rocket motor, batteries, telemetry and tracking systems, and a payload attachment fitting. On command from the Centaur's digital computer unit 70 seconds after Centaur main engine cutoff (MECO-2) the Delta is spun up to 100 r.p.m. Two seconds later the Centaur separates and backs away. The vehicle is now controlled by the Delta stage timer and pyrotechnic ignition delay train which the Centaur starts two seconds before separation. Fourth stage ignition occurs 42 seconds after separation and burns for 44 seconds followed 72 seconds later by Helios separation (Table 1).

All Titan III-E/Centaur flights use Complex 41 of the Titan III Complex, Air Force Eastern Test Range. Complex 41 is at present under operational assignment to the NASA Kennedy Space Center and necessary modifications were funded by the space agency.

Responsibilities

Responsibilities for Project Helios are allotted as:

Programme management: Bundesministerium für Forschung und Technologie (Ministry for Research and Technology)

Project management: Deutsche Forschung und Versuchsanstalt für Luft und Raumfahrt (German Aerospace Research and Experimental Establishment)

NASA Project management: Goddard Space Flight Center

Tracking and Data Acquisition: Deep Space Network

Launch Operations: Kennedy Space Center

Mission Control: German Space Operations Centre (Jet Propulsion Laboratory for first three weeks)

Spacecraft Contractor: Messerschmitt-Bölkow-Blohm GmbH

Launch Vehicle: Lewis Research Center

Launch Vehicle Contractors: Titan – Martin Marietta Corporation, Centaur – General Dynamics/Convair, TE-M-364-4 – McDonnell Douglas.

Helios Missions

Named after the Sun god of ancient Greece, Project Helios will cost a total of about $260 million for the two planned missions. Of this sum the German share is the greater at about $180 million leaving the United States to find the balance of $80 million. The German Ministry for Research and Technology pays spacecraft costs, included in which are the two operational flight craft, a prototype, and thermal, structural and engineering models. Also included in the German share are seven on-board experiments, and command and data acquisition costs for the German ground stations. Two launch vehicles and associated support, tracking and data acquisition services, three U.S. experiments, and other support come out of the U.S. share of the project.

Helios type missions are slightly unusual in that they can be launched virtually any day year-round. Earth-Sun relationship and launch azimuth constraints dictated by safety considerations serve to narrow the launch window to approximately one hour within any 24-hour period. However, on certain occasions, this window may be further limited to 45 minutes by tracking considerations.

Pre-launch activity for Helios-1 began on 17 June 1974 with arrival of the Titan first and second stages at the Kennedy Space Center followed by Centaur on 9 July. During July the Titan stages and Centaur were erected on their transporter in the Vertical Integration Building (VIB) at the Titan III Complex. In late August electrical and combined systems tests began before the vehicle was moved to the Solid Motor Assembly Building (SMAB) where the solid boosters were mated to the core vehicle in early September. The launch vehicle was transferred a distance of 2.8 miles to Pad 41 on 13 September.

On 16 July the prototype Helios spacecraft arrived at KSC and was erected atop the Titan/Centaur following checkout at Cape Canaveral Air Force Station. In October the

Table 1. Typical Flight Events for Helios

Flight Events	Sec.	Min. & Sec.	Kilometers	Miles	Km/hr	m.p.h	Km	Miles
Solid Motor Ignition	0	0	0	0	0	0	0	0
Stage I Ignition	111.4	1:51.4	43.1	26.9	4,917	3,055	39.7	24.7
Solid Motor Jettison	122.7	2:02.7	57.7	35.9	5,304	3,295	46.5	28.9
Stage I Cutoff	260.2	4:20.2	-	-	-	-	-	-
Stage II Ignition	260.9	4:20.9	394.7	245.3	14,632	9,092	111.7	69.4
Centaur Shroud Jettison	321	5:21	645.4	401.2	16,292	10,123	138.6	86.1
Stage II Cutoff	467.5	7:47.5	1,421.6	883.4	23,749	14,756	166.2	103.3
Stage II Jettison	473.5	7:53.5	1,460.5	907.5	23,786	14,779	166.8	103.7
Centaur MES-I (Main engine start)	483.7	8:03.7	1,525.9	948.2	23,783	14,777	167.8	104.2
Centaur MECO I (Main engine cutoff)	581.6	8:41.6	2,191.5	1,361.7	26,585	16,519	169.9	105.6
Centaur MES II	1,414.7	23:34.7	8,189.4	5,088.7	26,636	16,550	163.6	101.7
Centaur MECO II	1,687.7	28:07.7	10,559.5	6,558.3	39,224	24,369	233.6	145.1
Centaur/4th Stage Separation	1,759.7	29:39.7	11,297.2	7,020.2	38,942	24,197	328.3	204
4th Stage Ignition	1,801	30:01	11,719.5	7,282.2	38,712	24,055	406.9	252.8
4th Stage Cutoff	1,845	30:45	12,198.8	7,580	49,768	30,924	516.6	321
Helios Separation	1,917.8	31:57.8	13,064.7	8,118	49,180	30,562	793.5	493

vehicle successfully underwent a Terminal Countdown Demonstration to prove flight readiness.

Helios-A was received on 28 September for checkout, experiment integration and buildup which continued until early November. On 10 November the operational spacecraft was transferred to the Spacecraft Assembly and Encapsulation Facility (SAEF) for mating with the Delta fourth stage vehicle. This occurred on 18 November followed two days later by encapsulation in the payload shroud. The prototype spacecraft having been demated on 24 October the flight spacecraft was moved to Pad 41 on 24 November for mating with Titan/Centaur. The complete space vehicle later underwent Launch Readiness Verification and Launch Composite Electrical tests to clear the way for launch.

Helios-A (Helios 1) was launched on 10 December 1974, while the second probe, Helios-B, is scheduled for liftoff no earlier than December 1975.

REFERENCE

1. M. W. Howard, Titan III-E/Centaur, *Spaceflight*, July 1974, 277-278.

SPACE REPORT

Continued from page 183]

SPACE ASTRONOMY

Telescopes and spectrographs making it possible to explore astronomical objects of 15th and 16th magnitude from orbiting spacecraft are being discussed, writes Pyotr Klimuk in the magazine *Aviatsia i Kosmonavtika*. It is planned to make wide use of television. TV cameras will transform ultraviolet spectra received for reception on Earth. He also mentions "interesting projects" in extra-terrestrial radio-astronomy. A radio telescope with a 5 metre (16.4 ft.) reflector is thought to be equivalent to a ground instrument with a dish of 25-30 metres (82-98 ft.) diameter. In 1973 Klimuk made a flight in Soyuz 13 which carried the Orion 2 observatory.

EARTH'S WATER BALANCE

Soviet hydrologists report that 550,000 cubic kilometres of water in the form of rain, snow and hail fall to Earth every year. This is 40 per cent more than previously supposed – a volume equal to 45 Mediterranean seas.

The information is contained in *The World's Water Balance and Water Resources* published by Gidrometeoizdat, the publishing house of the Soviet weather service in Leningrad. The publication sums up the work of Soviet scientists under the programme of the International Hydrological Decade (1964-74) and includes input from satellite observations.

Total water reserves are given as 386 million cubic kilometres of which the oceans account for 96 per cent. This is 32 million cubic kilometres less than previously estimated and reflects the use of revised data on the relief of the ocean bed. The authors note at the same time that the level of the world's oceans has increased by 8-10 cm in the past 70 years.

In descending order water is "preserved" in glaciers and eternal snows, subterranean basins, lakes, atmosphere precipitation, swamps and rivers. The volume of so-called "biological water", i.e. that contained in living organisms, is put at 1,120 cubic kilometres.

MARINER-VENUS-MERCURY 1973 PROJECT HISTORY

By David Baker

PART 2

Continued from April issue page 133]

Controlling the Spacecraft

On into December 1973 sailed Mariner 10, still partially afflicted by the lack of TV heater operation and electron counts from the scanning electrostatic analyser. Attitude control gas remained normal with an average 0.01 lb. of propellent/day used during the cruise portion; about 6.77 lb. remained by the end of the first week of December. To date about 2,450 commands had been sent to the spacecraft through the prime DSN stations. Continued tracking of the spacecraft confirmed the 970 mile overshoot resulting from the first TCM burn when the trajectory was corrected from a 31,000 mile pass on the sunlit side of the planet to one aimed at a 3,600 mile pass on the dark side. To provide a post-Venusian trajectory aimed at a 625-mile pass at Mercury the encounter window at Venus allowed an error of only 150 miles. If Venusian pericentre occurred outside this zone the on-board propulsion would be incapable of refining the desired pericentre at Mercury.

Despite reoccurrence of the Power-On Reset problem a successful roll calibration manoeuvre was performed on 8 December when controllers allowed sufficient time for systems reset in the FDS. By 13 December attitude control gas usage was down to 0.009 lb./day with a tanked reserve of 6.64 lb. Mariner 10 was now 8.7 million miles from Earth and 33.8 million miles from Venus. By 14 December solar radiation was increasing the solar cell temperatures beyond the desired 212°F level and both panels were rotated 25° off the Sun-line to reduce temperatures by 18°F. One panel was tilted 12° and the other 40°, both moving in the same direction. The solar cell panels have a rotation capability of 76°. On 19 December the fourth roll calibration manoeuvre was performed without any of the POR anomalies seen earlier. At the end of Mariner's 8th roll the star tracker failed to lock on Canopus but commands from JPL stopped the tracker on the 9th roll. Only the previous day the scan platform had been tilted to its maximum (122°) so that the UVS airglow experiment could monitor emissions of interstellar helium but a detected bulkiness in operating the platform prevented further operations on the Gum Nebula.

December 23 saw Dr. Richard Goldstein of JPL using the 210 ft. DSN antenna for radar images of the surface of Venus so that TV pictures from Mariner 10 could be interpreted in association with surface profiles. (A repeat scan was again made on 28 December). Christmas Day, 1973, brought a serious problem to Mariner 10 when a section of the feed system of the steerable dish antenna failed, causing a drop in radio signal power. Simulations on the ground indicated that a joint in one of the feed system's two probes could have cracked under thermal stress but the antenna restored itself for four hours on 29 December before failing again. Then, during the evening of 3 January 1974, the problem again cleared up when feed temperature increased. If the anomaly reappeared Mercury TV views would be transmitted at the slower rate of 22.05 kbps versus the planned 117 kbps. This would provide a reduced quantity of high resolution mosaics over a smaller area. Mariner 10 was now 13 million miles from Earth, 18 million miles from Venus and travelling at a solar reference velocity of 68,500 m.p.h.

The antenna feed system again failed at 04:33 GMT on 7 January with a 3dB loss in downlink signal, an 11DN indicated low gain antenna drive and temperature increase in the feed system. JPL decided not to command any corrective procedure but rather to perform extensive ground analysis of the situation. On 7 January the scan platform was tested in a simulation of motion during planetary encounter but another potentially serious problem was noted on 8 January. At precisely 14:39 GMT Mariner 10 switched its primary power processing system to the redundant back-up system. This caused a 7 minute loss of telemetry through the DSN station at Madrid. January 10 provided an opportunity for slewing the scan platform into a position whereby the UVS airglow instrument could make observations of the comet Kohoutek on 19, 22 and 24 January. The comet would be leaving the vicinity of the Sun at a distance of 60 million miles from the spacecraft. By 16 January Mariner was nearly 17 million miles from Earth and 9.5 million miles from Venus.

Final Trajectory Correction for Venus

Attention now turned to the final trajectory correction manoeuvre, TCM-2, before encounter with Venus. Some 2,600 Earth-Mariner measurements of relative velocity and 2000 measurements of distance had refined the precise burn requirements, velocity vectors and ΔV, required to move the spacecraft 970 miles closer to Venus. This, it will be remembered, was the miss distance resulting from the TCM-1 operation on 13 November 1973.

On 17 January, while equipment was being turned off in preparation for the manoeuvre, the TV heaters suddenly came on. They had failed to come on following spacecraft separation shortly after injection. Also on 17 January engineers decided not to perform TCM-2 on schedule the next day but instead to prepare a new attitude strategy which would use a smaller pitch turn to retain use of the solar cells and prevent a switch to battery power alone. Commands were uplinked to the central computer and sequencer (CC & S) aboard Mariner 10 on 20 January. At 18:50 GMT on 21 January Mariner 10 rolled 46°, then pitched 35° and at 19:14 GMT burned its monopropellent rocket for 3.7 sec. This provided a ΔV of 5.5 ft./sec. and trimmed the trajectory to match the required fly-by distance of 3,600 miles.

By 23 January the scan platform was given its final pointing calibration and the TV cameras took three sequences of test pictures covering star clusters before being turned off. Because the platform had exhibited anomalous response when commanded to its highest pointing angles it was constrained to a slew angle of 107° instead of the design limit of 122°. This would eliminate several high angle views of Venus without compromising the photo' plan for Mercury. A final roll calibration manoeuvre was performed on 28 January and at the end of each of 8 rolls the scan platform was moved in cone to permit UVS airglow monitoring of diffuse UV emissions over a wide region of the sky. However, oscillations in the roll gyro rate telemetry channel signalled a depletion of nitrogen gas from the attitude control system. This was halted when the gyro was turned off but not before 20% of the gas had been lost, lowering supplies from 6.0 lb. to 4.7 lb. Instead of operating on inertial (gyro) stabilisation at Venus encounter Mariner 10 would hold attitude on the Sun and Canopus thus easing the gyro problem. By 1 February Mariner 10 was 25.5 million miles from Earth and 1.7 million miles from Venus.

More Venusian radar maps were made through the 210 ft. Goldstone antenna between 31 January and 2 February. On 4 February the high-gain antenna problem disappeared for two minutes and then restored itself to a less serious situation thereafter.

The first TV views of Venus were taken at 16:21 GMT on

Tuesday, 5 February 1974. Pictures would now be coming in every 42 seconds. Heading for a pericentre on the dark side of the planet Mariner 10 observed the twilight cusp at 16:46 GMT from a distance of more than 5,000 miles. Pericentre came at 17:01 GMT when the spacecraft swept past Venus at a distance of 3,585 miles. The TCM-2 burn had put Mariner to within 15 miles of the pre-flight aim point after a flight of 107 million miles. Range to Earth was 27.4 million miles and at precisely 17:07 GMT Mariner entered occultation for 21 minutes during which time some 36 TV views were recorded by the on-board tape recorder for subsequent playback. Planetary strip photography began at 18:20, followed by the first TV mosaics at 20:25 GMT.

Science operations continued through the night and on into 6 February until encounter TV operations were halted at 13:15 GMT. Playback of the occultation data began at 13:20 GMT and was completed by 15:37. During this period the CC & S was updated to provide continual far encounter views and this operation began at 15:40. On 9 February the picture-taking sequence was reduced to one view every 8 hours with 86-view mosaics shot every 12 hours. The cameras were turned off during the intervals to preserve the operating life of the vidicons. The last views of Venus were taken on 13 February, bringing the total number of pictures to 4,165. Also that day, preparations for the upcoming TCM-3 burn, to realign the pericentre at Mercury, necessitated a gyro turn-on but several minutes before this could begin all contact with Mariner 10 was lost for several seconds. The gyro's were tested the following day but oscillations were noticed during the third cycle and again on the fifth. This caused consumption of about 0.4 lb. of nitrogen attitude control gas and TCM-3 was postponed to the middle of March. By then the spacecraft would be in the correct celestial attitude for a Sun-line rocket burn without the need for wasting attitude propellent on roll or pitch manoeuvres. This would still permit targeting for a 625 mile pass over the dark side of Mercury but pericentre time would be put back by 37 minutes. Only a minimum of science data would be lost and at this stage of the flight conservation of attitude control gas had a very high priority.

In the late evening hours of 17 February the star tracker was attracted by a bright object causing Mariner to lose lock on Canopus and hunt back and forth with the gyro's on. About 0.07 lb. of attitude control gas was lost before the tracker finally locked up on Canopus again. By 19 February Mariner 10 was 37.5 million miles from Earth and 41 million miles from Mercury, travelling at a solar reference velocity of 80,300 m.p.h. Again, on 27 February the star tracker was attracted by a bright object in the field of view but regained lock on Canopus before the gyro's came on. The frequency of these light spots had increased from 1 or 2/week after launch to 10/week, probably indicating a brightening of dust particles in the increased light intensity of the Sun. A day later the increasing temperature of the solar cells necessitated a further panel rotation about the long axis to the 68° position. A second step-rotation procedure was made on 1 March. Then, on 4 March, the high-gain antenna restored itself to full operational capability and re-introduced the possibility of using the 117 kbps data transmission rate at Mercury. On 6 March the Canopus tracker again lost lock and used a small quantity of attitude control gas before locking up again on its target star. Two days later ground commands uplinked the CC & S so that gyro switch-on would be inhibited if any further distractions wandered into the field of

Mercury's south pole photographed by Mariner 10 as the spacecraft made its second flyby on 21 September 1974.

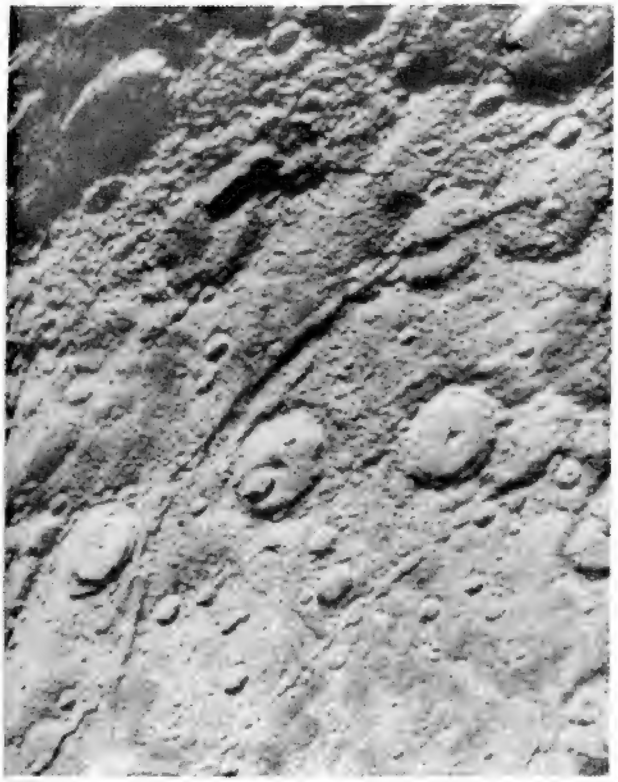
All photographs National Aeronautics and Space Administration

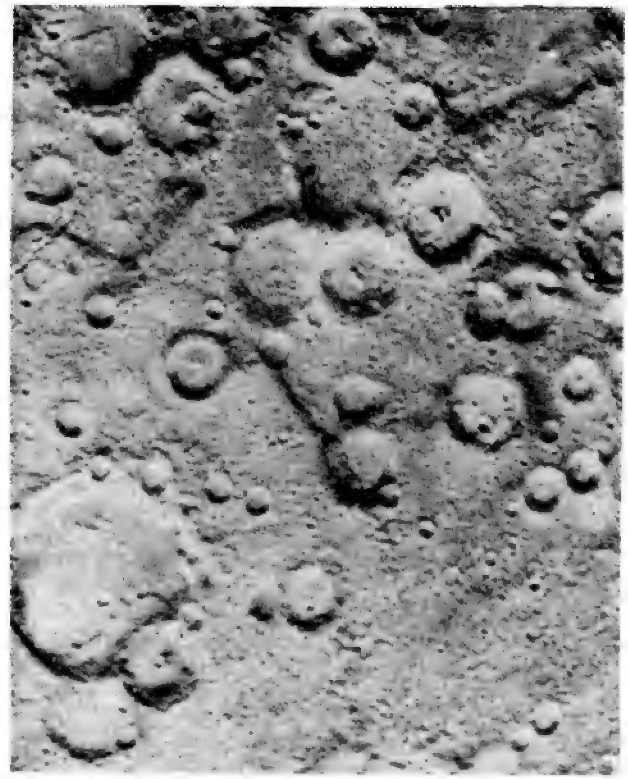
view. This would permit more precise control over nitrogen consumption.

When the Canopus tracker again lost lock, on 11 March, the roll axis was not orientated on the star but judicious alignment manoéuvres with the solar panels, one at 66° and the other at 66.5°, provided a torque counter from the pressure of the solar wind to the normal drift rate of the spacecraft. No attitude gas was lost. By 15 March the Sun-line correction burn, scheduled for the next day, was finally calculated so that Mariner 10 could achieve a planned 625 mile pass on the dark side of Mercury. The spacecraft was now 65 million miles from Earth and 8.5 million miles from Mercury.

Manoeuvres for Mercury

TCM-3, as the new Sun-line manoeuvre was called, combined the two course corrections originally planned for 4 days after encounter with Venus and 4 weeks prior to pericentre at Mercury. It was being made precisely at that time when the spacecraft reached the desired attitude reference for the burn, so preventing the use of nitrogen gas for deliberately changing attitude at the original TCM-3 time. Without this correction Mariner 10 would pass 6,711 miles on the Sun-side of the planet. The manoeuvre came at 11:54:42 GMT on 16 March with ignition of the hydrazine motor. About 51 seconds later the burn was over after imparting a ΔV of 58 ft./sec. Because the Sun was continually in the field of view of the sensors a more accurate determination of the pitch and roll position was instantly available on telemetry. The angle between the thrust line and the Earth-spacecraft line was 103°. Because of this the Doppler shift could show only a small component ($\Delta V \cos 77° \sim 13$ ft./sec.) and 10 days of tracking would be necessary to calculate a precise pericentre value resulting from the burn. Careful examination of the attitude of the spacecraft during the manoeuvre revealed a true velocity/spacecraft-Earth angle of 76.75°, about 0.25° off nominal. This would have produced a 2% increase in observed velocity along the spacecraft-Earth line. However, telemetry of the thrust chamber pressure indicated the burn had been 10% smaller in magnitude





Focus on Mercury. *Top left,* a scarp, or cliff, more than 185 miles (300 km) long extends diagonally from upper right to lower left in this Mariner 10 picture taken on 21 September 1974. Such structures are believed to be formed by compressive forces due to crustal shortening. Picture was taken from a distance of some 40,000 miles (64,500 km). *Right,* densely cratered region of Mercury obtained by Mariner 10 on 21 September from a distance of about 47,000 miles (76,000 km). Picture shows a scarp 7,500 ft. (2 km) above the surrounding area – part of a large system of faults which extends for hundreds of kilometres.

National Aeronautics and Space Administration

Taken about 40 minutes before Mariner 10 made its closest approach to Mercury last September, this picture shows a large double-ringed basin (centre) 142 miles (230 km) across located in the planet's south polar region (75°S latitude, 120°W longitude). Picture was taken from a distance of about 44,000 miles (71,000 km).

than planned. Because of this the observed Doppler shift of 63.4 Hz was only 1% higher than expected. Encounter altitude at Mercury was predicted to be about 466 miles on the dark side of the planet.

Mariner 10 was now heading for its prime target. The science instruments had been selectively optimised around the desired objectives at Mercury and the encounter sequence was divided into five separate phases. Approach photography would provide 90% coverage of the sunlit portion of the planetary disc at a resolution of 1.5 miles, 30% coverage at a resolution of 0.8 mile and specific areas at a resolution of 1,000 ft. The Incoming Far Encounter Sequence (IFES) began at 11:00 GMT on 23 March and continued to 02:20 GMT on 29 March. During this time about 216 frames were recorded aboard the spacecraft on 6 tape loads, simultaneously transmitted at low-resolution format. The taped views were played back later at high resolution. Real-time transmission allowed controllers to check the albedo of the surface and determine the reflective qualities at varying light angles. High resolution replay of the tape load was used to construct mosaics. During the IFES phase a search was made for possible moons and TV images were used for precise determination of the degree of oblateness in the visible disc.

The Incoming Near Encounter Sequence (INES) began at 04:35 GMT on 29 March and lasted through to 17:12 GMT. About 144 views were recorded during this period with full disc mosaics programmed at 05:31. The final mosaic was used for mapping high resolution views in the upcoming encounter phase. The INES also included eight UVS airglow scans with the platform slewing 10° back and forth. The IFES phase had covered the approach from 3.3 million miles to 420,000 miles, and the INES phase had narrowed the distance from 369,000 miles to 77,500 miles.

Mercury Encounter Sequence

Now began the all important Mercury Encounter Sequence (MES) which would last from 17:12 GMT, 29 March, to 02:11 GMT, 30 March and cover the pericentre time. In this period Mariner 10 took 612 high resolution views for real-time transmission, with 35 taped for later replay. The UVS airglow experiment performed planetary scans at 17:46, 18:46 and 19:46 GMT. Continuously, throughout the encounter phase, the Plasma Science, Magnetometer and Charged Particle Telescope experiments sought information on the interaction of the solar wind with a possible magnetosphere while measuring magnetic field strengths up to and following pericentre. The infrared radiometer provided details of thermal levels on the surface of the planet. Closest approach came at 20:46 GMT when Mariner 10 swept to within 460 miles of the surface. The spacecraft entered solar occultation at 20:42 and re-emerged into sunlight at 20:49 GMT. Less than one minute later it passed behind the planet as viewed from Earth for a duration of 13 minutes. Solar reference velocity just prior to closest approach was 135,000 m.p.h. as Mariner 10 swept past Mercury at approximately 30,000 m.p.h. Just as the spacecraft had exchanged energy with Venus to achieve this Herminian encounter, so again the energy transfer at Mercury would put the spacecraft on to a trajectory for re-encounter 176 days later when the planet had completed two revolutions of the Sun.

The Outgoing Near Encounter Sequence (ONES) covered the period from 02:11 GMT on 30 March (5,890 miles from the planet) to 23:36 GMT (620,000 miles). Additional UVS scans were made together with 144 frames of TV providing mosaics of the sunlit disc. The Outgoing Far Encounter Sequence (OFES) lasted from 02:12 GMT, 1 April to the early morning hours of 12 April. About 500 views were taken, with UVS scans terminating on 5 April. Distance covered during the OFES phase was more than 4 million miles. The last TV pictures were taken on 3 April at a distance of 2.2 million miles.

More than 2,000 frames had been received by the DSN stations during the 13 days of TV encounter operations. No TV was possible during the 30 minute period centred on closest approach due to the limits placed upon the scan platform when slewing to within 58° of the Sun. Far-side imaging began from a distance of 3,600 miles while Mariner 10 was still in Earth occultation, recorded on tape and replayed later.

Mercury Second Encounter

As Mariner sped away on its path around the Sun preparations got under way for the TCM-4 burn which would optimise the trajectory for a second encounter on 21 September 1974. Mariner would climb back out beyond the orbit of Venus and then fall in toward the Sun again, repeating its close pass with Mercury at spacecraft perihelion (which, incidentally, is close to planetary aphelion). Because most of the atmospheric data had been acquired at Mercury 1 (first encounter) the second pass would be a photographic run on the sunlit side of the planet. Without further manoeuvres Mariner would pass to within 500,000 miles of Mercury on 22 September.

TCM-4 was to be a two-part manoeuvre, moving the fly-by altitude closer to the planet. On 9 May 1974, at 19:44 GMT, Mariner began orientating its fixed thrust axis to the desired coordinates with a 16 minute roll of 181° and a 2.5 minute pitch of 27.5°. At 20:05 GMT the rocket motor ignited for a 195 second burn, changing spacecraft velocity by 162.5 ft./sec. TCM-4A had moved the point of closest approach to within 177,500 miles of Mercury. The second phase, TCM-4B, began at 19:44 GMT on 10 May with a 178° roll and a pitch of 36°. Ignition came at 20:06 GMT with a 139 second burn producing a ΔV of 90 ft./sec. The effect of this burn was to move the pass altitude to 19,650 miles from Mercury for a close encounter at 21:46 GMT on 21 September 1974.

During both manoeuvres attitude control gas usage was entirely nominal and of the 393 ft./sec. ΔV capability loaded at launch only 51 ft./sec. remained for trimming the second Mercury encounter point. Some consideration was being given to the desirability of performing a third course correction so that further study of the magnetic field could be made on the dark side of the planet. A 5,000 mile pass would be made if scientific analysis required this additional inspection. Balanced against this, of course, would be the loss of TV views of the sunlit side.

By early June 1974, project management had reviewed the spacecraft systems, examined the options and decided to optimise the second Mercury encounter altitude around the onboard propulsion capability to execute trim manoeuvres for a third encounter on 16 March 1975. Presently, the 19,650 mile Sun-side pass on 21 September 1974, would place Mariner 10 on a trajectory which would bring it back to within 250,000 miles of the planet at 18:10 GMT on 15 March 1975. However, by performing another course correction early in July 1974, Mariner could be made to move closer to the planet at encounter three by increasing the fly-by altitude for the second pass, providing a wider range of options.

WALLOPS FLIGHT CENTER

By Mike Howard

Introduction

Off the coast of Virginia, separated from the mainland by two miles of marsh and inland waterway, lies Wallops Island. This 6-mile long and 1-half-mile wide island takes its name from John Wallop, a 17th century surveyor. It was here that, in 1945, a launch site was first established by the Langley Research Center, itself a field station of the National Advisory Committee for Aeronautics (NACA).

Wallops' History

Designated the Pilotless Aircraft Research Station, the Wallops launch site was intended to supplement wind tunnel and laboratory investigations into the problems associated with flight. When the National Aeronautics and Space Administration succeeded NACA in 1958, the site became a separate field station in its own right under the name of Wallops Station. Under its new title Wallops operated until 1974 when it was re-designated Wallops Flight Center.

Since 1945 Wallops has launched more than 8000 research vehicles consisting of up to seven rocket stages. Most of the missions have been designed to gather scientific information on the flight characteristics of aircraft, launch vehicles and spacecraft, and to increase knowledge of the upper atmosphere and space environment. Each year several hundred experiments are launched by vehicles varying in size and power from the small sounding rocket to the four-stage Scout.

During 1959-61 several spacecraft capsules were test launched at Wallops by the Little Joe Booster in support of Project Mercury. In preparation for the launches of the Echo 1 and Echo 2 passive communications satellites a series of 100 ft. diameter inflatable aluminium-coated mylar spheres was flown from Wallops in suborbital flights during 1959-60. Late 1962 saw the launch of an experiment to check out some of the instruments scheduled for use aboard the Orbiting Astronomical Observatory (OAO). In 1964 a re-entry experiment was flown atop a Scout booster to test heatshield material under study for use on Apollo spacecraft. A Weightless Analysis Sounding Probe (WASP) was launched in 1966 to study the behaviour of liquids under zero gravity conditions. Data from WASP were used in the development of Centaur and Saturn vehicles where the liquid-fuelled upper stages are designed to operate and restart in orbit.

Wallops Today

Wallops Flight Center comprises three main areas. The Main Base, which occupies 2200 acres six miles north-west of Wallops Island, is the location of the administrative offices, technical service support shops, rocket inspection and storage area, experimental research airport, Range Control Center, main telemetry building and a National Oceanic and Atmospheric Administration (NOAA) Command and Data Acquisition Station. Wallops Island itself is connected to the mainland by a causeway and bridge. The Island contains the launch sites, assembly shops, blockhouses, dynamic balancing facilities, some rocket storage buildings, and associated facilities. The third element of the Center is the Wallops Mainland, a half-mile strip at the inland end of the causeway. This site is the location of long-range radars, optical tracking sites, and transmitter facilities.

Wallops is somewhat unique in that it is the only NASA launch facility completely under civilian control. Approximately half the Center's personnel are engineers and technicians responsible for vehicle preparation, launching, tracking, and data acquisition.

The facility's primary responsibility today is to obtain and distribute scientific data about the atmosphere and the space environment for the benefit of all mankind.

Projects

Wallops Flight Center acts as project manager for several NASA programmes. The GEOS-C (Geodetic Earth Orbiting Satellite), the Experimental Inter-American Meteorological Rocket Network (EXAMETNET), the Polar Cusp Barium Project, operation of remote site launching and tracking facilities, and operation of NASA's portable range facilities for sounding rockets are all under the control of Wallops. The Center is also partly responsible for the National Sounding Rocket Program. Sounding rockets are used mainly to obtain data at altitudes between the maximum balloon level of 20 miles and the satellite level. During their lifetimes of a few minutes these small rockets travel vertically to provide information on high altitude wind velocity, density and temperature of particles in the upper atmosphere, properties and changes in the ionosphere, measurements of the brightness of stars and numerous other phenomena.

Over a 24 hour period in June 1974, no fewer than 54 sounding rockets were launched on suborbital trajectories varying in altitude from 35 to 100 statute miles (60 to 160 km). This concentrated scientific effort was called Project ALADDIN '74 – Atmospheric Layering and Density Distribution of Ions and Neutrons. More than 300 scientific and technical personnel from the United States, England, Canada, West Germany and Italy were involved in the project to study in detail the atmospheric structure and dynamics of the upper atmosphere. The firings utilized 24 launch pads at 6 sites on Wallops Island (see *Spaceflight* January 1975).

Aeronautics

A part of the Wallops Flight Center's activities covers aeronautical research. To this end grooves have been cut in one of the runways at the Center to study the effectiveness of this means of controlling aircraft hydroplaning on wet runways. This method of reducing skidding has already been brought into use on some highways in the United States where hydroplaning by motor vehicles is a hazard. Studies of new approach and landing procedures, pilot information displays, VTOL and STOL flight vehicles, helicopter stabilisation, and automatic landing systems also form a major part of Wallops' aeronautical research programme.

Acknowledgement

The writer wishes to thank the Wallops Flight Center's Office of Public Affairs for their assistance in presenting this material.

T 16

SATELLITE DIGEST — 82

A monthly listing of all known artificial satellites and spacecraft, compiled by Robert D. Christy. Information is based on that supplied by the Space Department of the Royal Aircraft Establishment, Farnborough and other sources. For information on the derivation of orbital parameters, abbreviations, etc., see July 1972 issue, p. 262.

Continued from April issue, p.153.

Name, designation	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclination (deg)	Nodal period (min)	Launch centre, launch vehicle and payload/launch origin
Cosmos 692 1974-87A	1974 Nov 1.60 11.7 days (R) 1974 Nov 13.3	Sphere-cylinder 4000?	5 long? 2 dia?	197	295	62.82	89.41	Plesetsk USSR/USSR
1974-87F	1974 Nov 1.60 22.32 days 1974 Nov 23.92	Sphere?	2 dia?	193	282	62.82	89.24	Plesetsk USSR/USSR (1)
Cosmos 693 1974-88A	1974 Nov 4.45 11.8 days (R) 1974 Nov 16.3	Sphere-cylinder 4000?	5 long? 2 dia?	219	243	81.33	89.14	Plesetsk USSR/USSR
1974-88E	1974 Nov 4.45 13 days 1974 Nov 17	Sphere?	2 dia?	182	215	81.53	88.49	Plesetsk USSR/USSR (2)
NOAA 4 1974-89A	1974 Nov 15.72 10000 years	Rectangular box + 3 panels 340	1.25 long 1.02 square	1447	1462	101.75	115.00	WTR Delta NOAA/NASA (3)
Oscar 7 1974-89B	1974 Nov 15.72 10000 years	8 sided cylinder 29	0.43 long 0.42 dia	1444	1462	101.74	114.97	WTR Delta RASC/NASA (4)
Intasat 1 1974-89C	1974 Nov 15.72 10000 years	12 sided cylinder 20	0.45 long 0.44 dia	1442	1462	101.73	114.95	WTR Delta Spain/NASA (5)
Cosmos 694 1974-90A	1974 Nov 16.49 12.8 days (R) 1974 Nov 29.3	Sphere-cylinder 4000?	5 long? 2 dia?	173 172	313 336	72.83 72.83	89.37 89.59	Plesetsk USSR/USSR (6)
1974-90E	1974 Nov 16.49 17 days 1974 Dec 3	Sphere?	2 dia?					Plesetsk USSR/USSR (7)
Cosmos 695 1974-91A	1974 Nov 20.50 6 months	Ellipsoid 400?	1.8 long? 1.2 dia?	273	468	71.00	91.96	Plesetsk USSR/USSR
Molniya-3A 1974-92A	1974 Nov 21.44 5 years?	Cylinder-cone + 6 panels + 2 antennae	4.2 long? 1.6 dia?	628 503	40685 39839	62.82 62.82	737.26 717.50	Plesetsk USSR/USSR (8)
Intelsat 4F 1974-93A	1974 Nov 21.99 indefinite	Cylinder + antennae 1410 (fuelled) 720 (empty)	2.82 long 2.39 dia	35781	35795	0.4	1436.2	ETR Atlas Centaur Comsat/NASA
Skynet 2B 1974-94A	1974 Nov 23.02 indefinite	Cylinder 129	0.81 long 1.37 dia	36255	36621	2.30	1469.5	ETR Delta UK/USAF
Cosmos 696 1974-95A	1974 Nov 27.49 11.8 days (R) 1974 Dec 9.3	Sphere-cylinder 4000?	5 long? 2 dia?	205	321	72.85	89.77	Plesetsk USSR/USSR

Supplementary notes:

(1) Ejected from 1974-87A during 1974 Nov 12.

(2) Ejected from 1974-88A during 1974 Nov 15.

(3) Improved Tiros Operation Satellite placed in Sun synchronous orbit, after launch control was passed from NASA to the National Oceanographic and Atmospheric Administration.

(4) Orbiting Satellite Carrying Amateur Radio, launched as a pick-a-back to NOAA 4. The satellite was built by a group known as the Radio Amateur Satellite Corporation.

(5) First Spanish satellite.

(6) Orbital data at 1974 Nov 17.5 and 1974 Nov 22.8.

(7) Ejected from 1974-90A during 1974 Nov 28.

(8) First Molniya-3 launch, this new type of Molniya appears to differ from the Molniya-2 in that improved TV equipment, capable of relaying colour TV pictures has been incorporated in the satellites design.

SPACEFLIGHT

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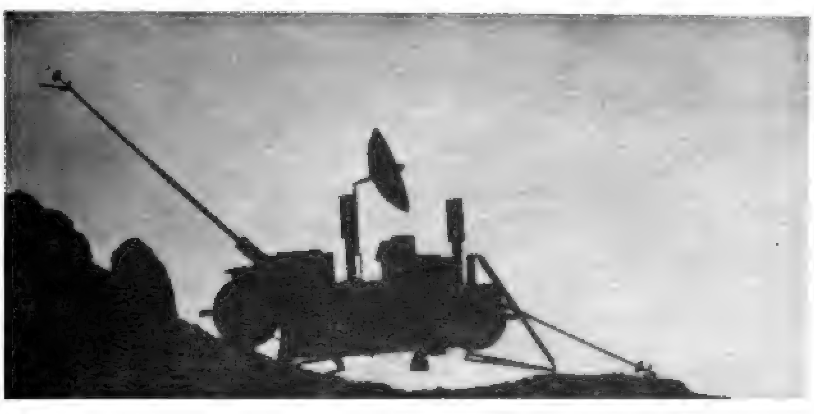

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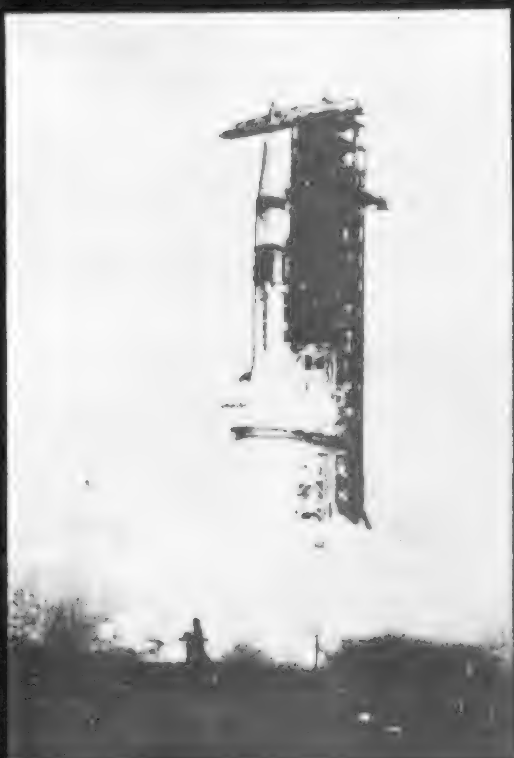

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CONTENTS

MISSION TO MARS. In August two Viking spacecraft will be launched from the Kennedy Space Center in Florida in the quest for evidence of life on Mars. These photographs show some of the preliminary tests. *Top left*, engineering model of the entry capsule which will protect the Viking lander as it enters the thin Martian atmosphere. *Right*, helium-filled balloon being prepared to carry the attached Viking test spacecraft to an altitude of 27 miles (43.4 km) above the Earth for drop-testing. This qualified the parachute braking system which will slow the Viking lander before terminal rocket braking for soft-landing. *Below*, Viking lander model on simulated Martian surface. For story see page 202.

Martin Marietta Aerospace

T 1

SPACEFLIGHT

A Publication of The British Interplanetary Society

VOLUME 17 NO. 6 JUNE 1975 — *Published 15 May 1975*

MILESTONES

March

14 ESRO Council designates Roy Gibson (UK) prospective Director-General of European Space Agency, following year-long dispute between France and West Germany over whether supremo should be French or German. Final approval of Gibson (acting Director-General since April 1974) and seven other directors expected when 10 European countries involved in ESRO/ESA meet for European Space Conference scheduled for 15 April. This Conference also to approve final transition of ESRO into ESA and decide whether ESA will contribute to running expenses of Guiana Space Centre where Ariane rocket should be launched in 1979.

16 *Tass* announces that Soviet carrier rocket will be launched between 17-31 March into an area of the Pacific within a radius of 40 n. miles centred 6°30'S/153°15'W.

18 U.S. Department of Defense reveals that two Soviet SS-18 ICBM's were fired from the central USSR into Pacific target area. Missiles, which travelled some 8,000 n. miles, had single re-entry vehicles. Two-stage, storable liquid propellent SS-18 is considered SS-9 replacement; can carry up to six multiple warheads in megaton range.

20 US and Soviet ASTP flight crews, in their respective simulators, begin combined rehearsals with countries' space centres linked. (Prime and back-up US ASTP astronauts scheduled to leave for final joint training session in USSR [and visit to Tyuratam cosmodrome] 12 April).

22 Orbit of Salyut 4 adjusted upwards to achieve 343 x 356 km x 51.6 deg; period 91.3 min.

26 Salyut 4 completes 1,425 Earth revolutions by 13.00 hr. (Moscow time). Onboard systems continue to function normally.

April

2 Luna 22, launched on 29 May 1974, by 11 a.m. (Moscow time) completes 2,842 revolutions of the Moon. After several trajectory corrections orbit ranges between 200 and 1,409 km above the Moon inclined at 21 deg to the equator; period 3 hr. 12 min. Instruments continue to function normally.

5 Launch vehicle of Soyuz spacecraft intended to carry Colonel Vasily Lazarev and Oleg Makarov to Salyut 4 space station goes off course due to third stage malfunction. Launch abort system operates automatically and command module soft-lands safely more than 1,600 km downrange south-west of Gorno-Altaisk in Western Siberia. (Lift-off probably occurred just after 12.00 hr. BST, according to the constraints of the launch window. Ed.

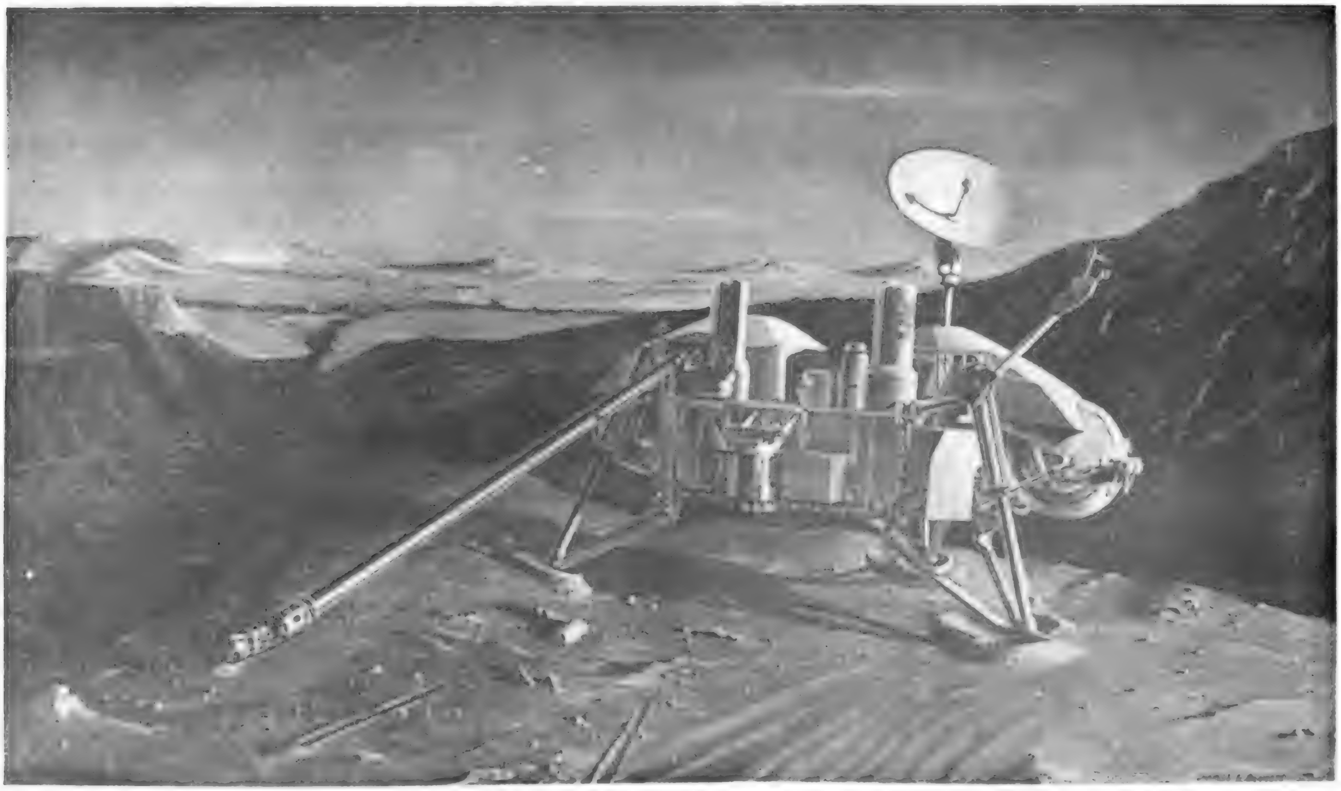
8 Prof. Konstantin D. Bushuyev, Soviet ASTP technical director, informs Dr. Glynn S. Lunney – his US counterpart – that Soyuz launch vehicle that failed on 5 April differed from ASTP booster in that the latter is "a modernised version, with greater payload capability."

15 European Space Conference in Brussels confirms establishment of European Space Agency and appointment of Roy Gibson as first Director-General.

15 B.I.S. launches three-year Development Programme and Appeal Fund with an initial target of £25,000 (see editorial, *Spaceflight* May 1975).

В журнале не печатается ряд страниц.

NINETY DAYS ON MARS



VIKING LANDER. This magnificent painting by Charles O. Bennett shows the mechanical scoop on the end of the spring-steel arm collecting a sample. Having grasped the material the scoop arm retracts to the spacecraft, swivels and stops over a cylinder covered by a wire grill. The lid of the scoop begins to vibrate and dust and soil particles drop through into a rotating conveyor in the spacecraft's interior which distributes measured quantities to a number of test cells for chemical analysis.

Martin Marietta

Our galaxy contains upwards of 100,000 million stars and their families of planets. Growing evidence suggests that Earth may not be the only life-bearing planet in this galaxy. Telescope studies have shown that Earth's basic chemicals are distributed throughout the Universe and organic compounds – life's building blocks – have been detected in interstellar space.

The two unmanned, automated Viking spacecraft are scheduled for up to 90 days of close-up examination of the features of Mars. Their scientific exploration of the planet has two purposes:

To seek evidence of whether life may exist on other planets.

To obtain information to improve our understanding of how Earth developed as a life-supporting planet and how we can better protect its environment.

If we find that life exists or has existed in the harsh climate of Mars, we will have strong reason to believe that planets with comfortable climates do support life and that other solar systems are inhabited.

Mars is presumed to have originated at about the same time and by the same process as Earth. Regardless of whether life is found there, the Viking atmospheric and geological studies of Mars will yield a wealth of information valuable in understanding Earth and formulating measures to protect our own environment.

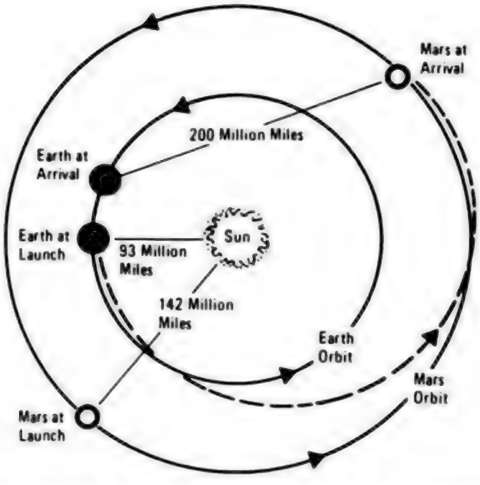
Viking is the most complex mission to be flown by NASA, requiring the four highly complicated science stations – two orbiters and two landers – to carry out separate coordinated operations simultaneously and over an extended period of time.

The 5,100 lb. orbiter will stay in orbit while the 2,400 lb. lander descends to the surface, as did the command module and the lunar module during the Apollo missions to the Moon. The Viking lander will use a parachute and retro-rockets to achieve soft landing. It will begin its programme of life-seeking biology experiments on about the 10th day after landing.

Photo's from orbiters and landers and information from the science experiments will be transmitted back to Earth by radio. Radio signals will require more than 20 minutes to travel the 200 million miles from Mars to Earth. Spacecraft tracking and communications will involve the Deep Space Network's stations at Goldstone, California, Madrid, Spain, and Canberra, Australia.

Programme Management

The Viking project is managed for the National Aeronautics and Space Administration by its Langley Research Center at Hampton, Virginia. As the programme's major contractor, Martin Marietta Corporation had the primary industry responsibility in developing the science instruments,



Viking flight profile. Each spacecraft will travel 440 million miles (708 million km) through space for almost a year, reaching Mars when the planet is on the opposite side of the Sun from Earth. Provisional launch dates are 11 and 21 August 1975.

Martin Marietta Aerospace

mission operations, and spacecraft to achieve the desired science objectives. Martin Marietta Aerospace designed and built Viking landers, science equipment and the Titan launch vehicles at its Denver, Colorado division.

The Jet Propulsion Laboratory in Pasadena, California, built the orbiters and provided facilities for spacecraft tracking and mission control. Sixty-six scientists of the United States and other nations will direct the project's scientific investigations.

Viking Scientific Investigations

The Viking spacecraft will make basically three investigations during their three-month observation of Mars from orbit and from two sites on the surface:

1. **A photographic survey of Mars;**
2. **A search for forms of life; and**
3. **An analysis of the physical features and makeup of the planet and its atmosphere.**

Photographic Survey

Each Viking spacecraft has an orbiter and a lander. Each orbiter carries two high-resolution television cameras, and each lander a pair of facsimile cameras.

During the last 180 hours of approach to Mars, each spacecraft will obtain a series of photographs of the globe from progressively closer range. After entering orbit, the spacecraft will remain above the designated lander sites to photomap these regions for a number of days before and after the landers are released for descent to the surface. Then the orbiters will leave their fixed positions above the lander sites to photomap almost the entire surface of the planet.

Orbiter photomaps and thermal and water vapour maps will be used to direct the landers to sites where conditions are more favourable to life and where landing hazards are less extreme. Lander cameras will take high-resolution photos of the ground immediately next to the landers, 360-degree panoramic views of the terrain and distant features, and long-range photos of Mars' satellites and celestial objects.

Instruments

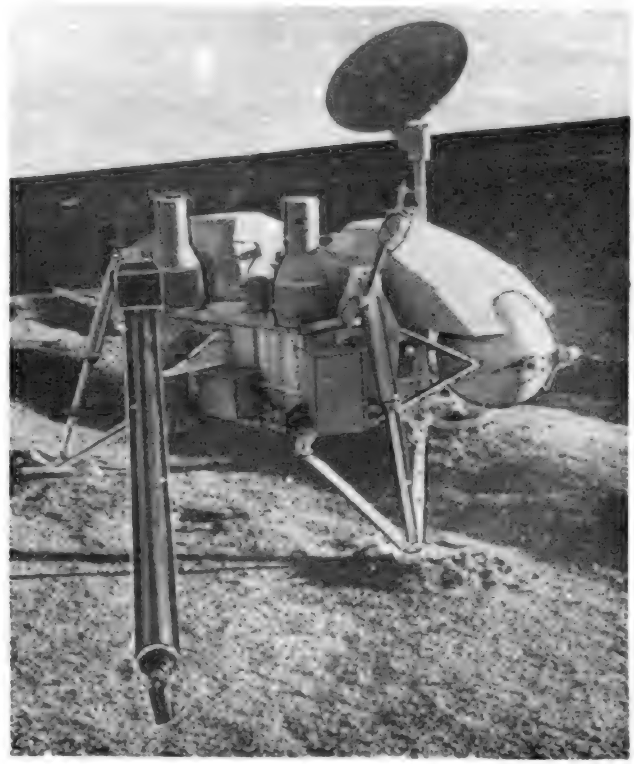
Orbiter Cameras. Rapid-sequence vidicon cameras using 475 mm telescopes. Taken from low-point in orbit (930 miles), a photo shows 25-square-mile area with resolution of 50 metres. Consecutive photos from one orbital pass show a 50 by 310-mile swath. Photos are stored on magnetic tape for playback to Earth.

Lander Cameras. Identical facsimile cameras mounted three feet apart on top of lander for stereoscopic black and white, colour, and infrared photos. Cameras can view from the ground beside the lander up to 40 degrees above horizon. Each uses a nodding mirror to scan a scene in tiny increments, requiring 20 minutes for a full scene. Light from the scene increments is converted into digital information bits which are radioed to Earth and reconstructed into a photograph.

The Long Journey

The two 7,500 lb. Viking spacecraft will be launched from Cape Canaveral by Titan III/Centaur rockets in 1975, one in August and the other in September. Each craft will travel 440 million miles through space for almost a year, reaching Mars when the planet is on the opposite side of the Sun from Earth. The spacecraft will reduce its velocity to be captured by Mars' gravity in an orbit of 930 by 20,500 miles, then will circle the planet 10 to 50 days for landing site reconnaissance.

The three-legged lander carries life detection experiments to determine if the Martian environment can, or in fact does, support life.



Close-up of the great volcano *Nix Olympica.* This volcanic mountain rises 15 miles (24 km) above a flat Martian plain and is 370 miles (595 km) wide at the base. Computer enhancement of more than 1,500 pictures used for the Mars globes sharply etch details of the surface as seen in this close-up.

National Aeronautics and Space Administration

In July 1976, if all goes well, an insect-like robot operated by instructions programmed into an on-board computer, will descend through the thin atmosphere of Mars to settle into a valley near the outlet of a canyon more than 18,000 ft. (5,486 m) deep. The huge rift valley runs out into a series of long channels resembling dried out river beds. The landing site, in the region of *Chryse*, is located 19.5°N, 34°W. Twin TV cameras will send pictures for colour reconstruction on Earth, and an automatic biological laboratory will begin the search for evidence of life. Later, a sister-craft will descend onto *Mare Acidalium* (44.3°N, 10°W) at the southern reaches of the north polar hood, a hazy veil which shrouds each polar region during the winter season and which may carry moisture. This article continues our review of Project Viking (see *Spaceflight*, September 1973, which included details of the landing sites). Maps of Mars, prepared from Mariner 9 data by C. A. Cross, appeared in *Spaceflight*, August 1972.

How Mars appeared to astronomers before the Mariner space probes filled in the details and disposed of the *canali.* Globe is inverted, as the planet appears through a telescope. North at bottom. Arrow marks *Nix Olympica.*

The Red Planet

Mars	Mean distance from Sun 142 million miles. Distance from Earth at closest approach 34.6 million miles. Orbits Sun in 687 days.
Physical Features	Diameter 4,200 miles (half that of Earth's). Gravity one-third that of Earth's. Temperatures up to 32°F in afternoons (possibly up to 80°F in some areas), down to 190° below zero at night. Nearly half of surface volcanic; largest volcano, *Olympus Mons,* 15 miles high and 310 miles wide at base (twice the size of Hawaiian Islands). Massive faulting of surface; great rift along equator 2,500 miles long, up to 150 miles wide, 4 miles deep. Extensive ancient arroyos, apparently dry riverbeds formed by massive flow of water. Polar caps of frozen carbon dioxide (dry ice) and water ice.
Atmosphere	About 1 per cent as dense as Earth's. Mostly carbon dioxide, small amounts of water vapour, traces of carbon monoxide, oxygen, and ozone. Cirrus-like clouds as high as 20 miles form each afternoon in vicinity of volcanoes, possibly from volcano venting of moisture; complex layers of cumulus clouds over polar caps. Surface winds up to 200 miles per hour.
Moons	Deimos, 6 miles wide and 8 miles long, orbits at 12,500 miles above Mars. Phobos, 12 by 17 miles, orbits at 4,000 miles.

Another view of the spectacular 'photo globe' of Mars – the first ever made of any body in the Solar System. It was prepared by the Jet Propulsion Laboratory of California Institute of Technology which managed the Mariner project for NASA.

National Aeronautics and Space Administration

Search for Life

Life may exist on Mars in higher forms like moss or lichens or in microscopic forms like viruses or bacteria. Or a rich variety of life may have existed at one time but disappeared later in the planet's history.

The two regions chosen for landings are areas where conditions could be conductive to Earth-like life forms. They are relatively low, temperate-zone sites in the northern hemisphere where there are indications of atmospheric moisture now and of surface moisture at least at some time in the past.

Higher forms of life and fossils, surface burrows or trails, and artifacts could be identified in the lander camera photos of the surface adjacent to the landers. The search for microscopic plant or animal life will be made in Martian soil samples. The samples will be scooped up by the 10-ft. lander boom and fed into automated biology test chambers where they will be observed for signs of photosynthesis and metabolism. Chemistry of the organic compounds in the soil will be analyzed for indications of whether they were produced by animal or plant life, or could evolve life.

The Viking spacecraft will be sterilized before launch to prevent contamination of Mars or the life-seeking experi-

Left: Global mosaic of Mars 4 ft. (1.22 m) in diameter is made of more than 1,500 computer-corrected television pictures taken by Mariner 9 in 1971-72. The residual North Pole ice cap is at the centre.

ments by Earth microorganisms.

Discovery of life on another planet would have a more profound effect on man's thinking than any other discovery in history.

Test for Photosynthesis

Photosynthesis is the basic life-sustaining process by which Earth plant life uses light energy to combine basic compounds like carbon dioxide, water, and salts – forming carbohydrates. Steps in the Viking photosynthesis test are:

(a) Inoculate three soil samples with carbon monoxide and carbon dioxide that bear radioactive tracers.

(b) Inoculate soil and gases under a lamp that simulates Martian sunlight.

(c) Evacuate any remaining free gas.

(d) Heat samples to 1,100°F to vapourize organic materials.

(e) Measure and analyze the vapourized materials.

Liberation of a substantial amount of tracer gas from the samples will be taken as strong evidence that plant-like organisms in the soil consumed the carbon monoxide and carbon dioxide in photosynthesis.

Test for Metabolic Activity

From a science standpoint, the Viking lander is the most complex spacecraft ever built. The biology unit will feed to three soil samples a nutrient of organic compounds like sugar which bear trace chemicals. Instruments will monitor gases given off by the samples over a period of about two weeks.

Steady production of gases by soil samples will be taken as evidence that organisms in the soil consumed the nutrient; steadily increasing production of gases will be taken as evidence of growth by the organisms.

Test for Respiration

Soil samples will be moistened with nutrients and surrounded in the test chamber with air from the outside, principally carbon dioxide. Constituents of the atmospheric sample will be monitored over a period of about two weeks. Changes in composition of the atmospheric sample will be taken as evidence of respiration from metabolism of organisms in the soil.

Test of Sterilized Samples

In parallel, a soil sample will be sterilized and subjected to the same tests as further validation of any positive results in the tests.

Biology Instrument

The complete range of experiments planned for Viking, if conducted on Earth with today's standard science instruments, would require thousands of pounds of equipment which would fill several ordinary size laboratory rooms.

The lander biology unit, in one cubic foot of space, contains: 3 automated chemical labs, a computer, tiny ovens, counters for radioactive tracers, filters, sun lamp, gas chromatograph to identify chemicals, 40 thermostats, 22,000 transistors, 18,000 other electronic parts, and 43 miniatures valves.

The Planet and its Atmosphere

Instruments of the orbiters and landers will examine the physical features and makeup of the planet and its atmosphere in minute detail. Comparison of the geology and climate of Mars with those of the much more complex Earth and the primitive Moon is expected to resolve many questions about the evolution of Earth and our Solar System.

One landing site is in a valley at the mouth of the giant surface rift, or grand canyon, of Mars. Here, deposits from exposure and erosion of geological features around the chasm are expected to be rich in information about the history and development of the planet.

We still lack a complete understanding of Earth's complex environmental systems; for example, what accounts for the patterns of movement of water vapour and pollutants in our atmosphere. Clues should be found in study of the dynamics of Mars' more rudimentary atmospheric system in the absence of civilized man.

Geology

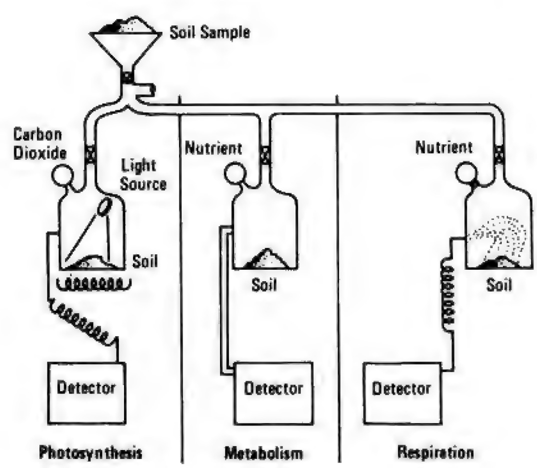
The orbiters and landers will conduct experiments to study surface geology and planet internal structure, and to determine whether the planet is geologically alive. Orbiter and lander photographs will identify types of land forms, stratification, folds, joints, faults, rocks, erosion, sediments, and soil, and will give indications of mineral and chemical composition. If there are Marsquakes in adequate number, lander seismic readings can determine whether the planet has a molten core, a mantle, and a crust as does Earth, and can allow comparison of the mantles of Mars and Earth.

Lander instruments will identify elements and minerals in the soil. Thermal mapping by the orbiters will allow search for ground frost and evidence of planet internal heat, and will aid in identifying surface structural character from difference in heat conductivity.

Viking radio and radar systems will provide information to improve our knowledge of the planet's size, mass, gravitational field, surface density, and electromagnetic properties, and atmospheric density and turbulence, and will allow study of the solar wind.

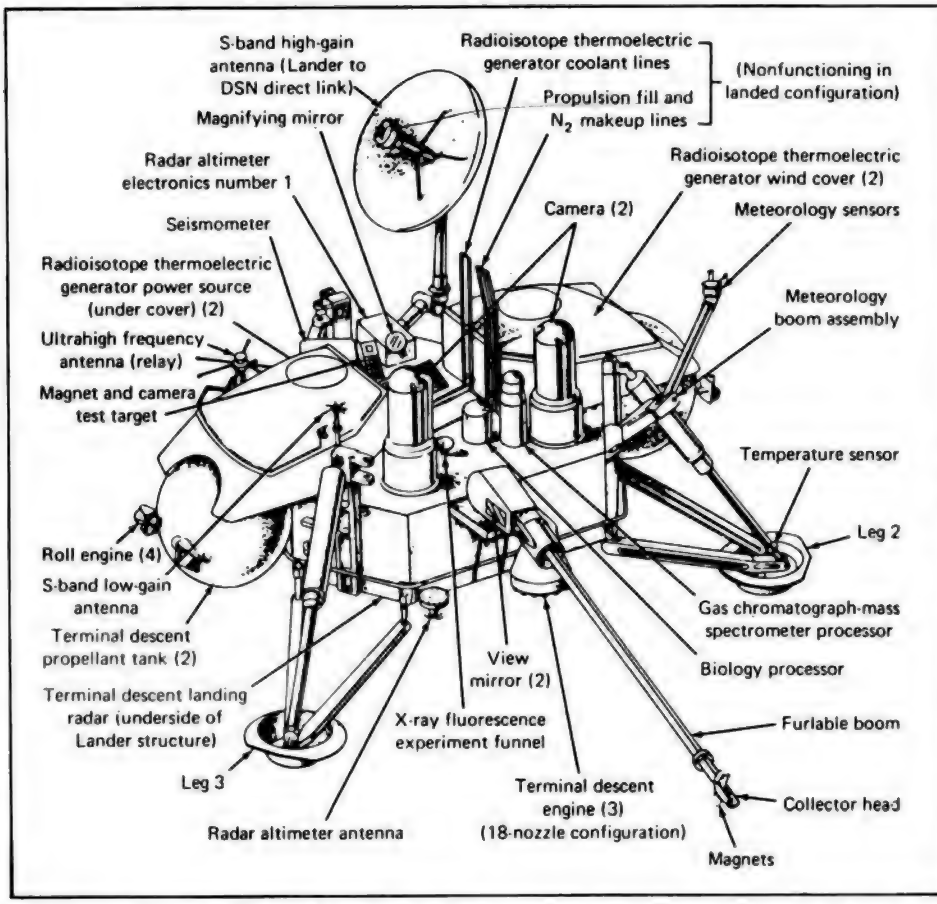
Science Instruments

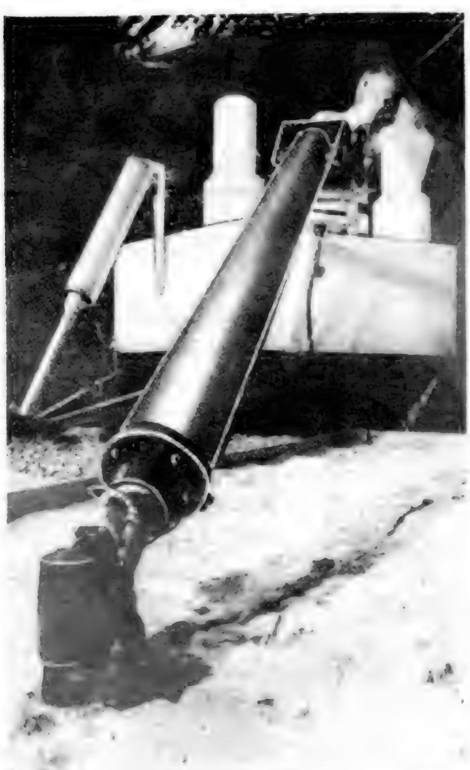
Infrared Radiometer. From orbiter, measures heat radiating



Viking biolab schematic: the three basic experiments.

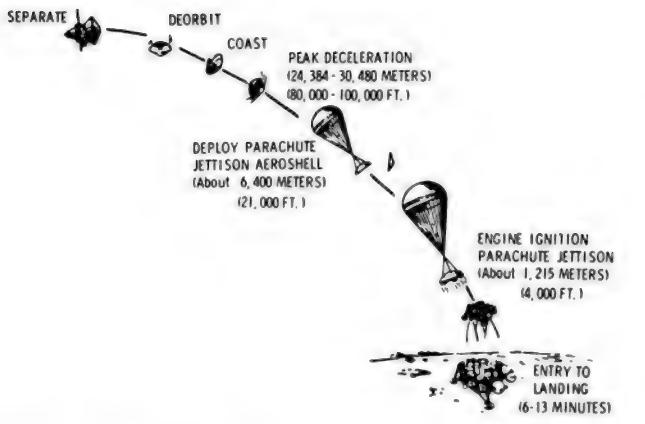
The Viking Lander. After landing, the Lander's cameras will take pictures of the terrain – some in colour and some employing both cameras to produce three-dimensional stereo pairs. Other instruments will collect atmospheric and meteorological data, and a seismometer will record Martian quakes and learn about the planet's interior. Surface geology will be examined with the cameras, the soil sampler, and inorganic analysis of soil samples to determine what elements are present.





Test model of Viking sampler. *Left*, soil gathered by the collector head is transferred by the retractable arm to a processing unit *(right)* for use in various chemical and biological analysis experiments. On Mars the Landers will deploy extendable booms that unroll like spring tape measures.

Martin Marietta Aerospace



Viking Lander descent profile.

National Aeronautics and Space Administration

from planet's surface. It can record temperatures in both the day and night hemispheres and is accurate within 2°C.

X-ray Fluorescence Spectrometer. Identifies basic elements in soil by measuring their fluorescence after being exposed to radioactive Cadmium 109 and Iron 55. It can detect elements present in amounts as small as 200 parts per million.

Gas Chromatograph-Mass Spectrometer. Identifies gases in the atmosphere and organic compounds in the soil.

Seismometer. Can detect volcanic activity, planet internal structure shifts, and impacts of meteorites on planet's surface. Will be used to determine whether landers are functioning properly by measuring their vibrations.

Soil Boom Scoop. Will be used to study characteristics of the soil: cohesiveness, porosity, hardness, particle size. Magnets mounted on sampler will determine whether soil contains magnetic materials.

Meteorology

Requirements for the Viking lander are space flight's most demanding: two days of sterilization baking before launch; ascent gravity and vibration forces atop a 1.4-million-pound rocket; 11 months' exposure to harsh space conditions; buffeting from Mars atmospheric entry, parachute opening and retrorocket firing; impact on surface of Mars at a speed of 4 ft. sec. Then it must function as a finely tuned, self-sufficient laboratory and data transmission complex for 90 days.

Landers as they enter Mars' atmosphere will analyze the ionosphere to determine the effect of the solar wind on the planet's atmosphere. As they descend they will record the temperature, pressure, and chemical content of the atmosphere at different altitudes.

The Orbiters will observe the formation and movement of clouds and record their temperatures for analysis of their composition. The lander mass spectrometer will analyze the amounts of carbon dioxide, oxygen, nitrogen, and other gases in the atmosphere at the surface during the first three days, before starting analysis of the soil.

Lander instruments will measure pressure, temperature, windspeed and direction periodically to log daily and seasonal variations in weather and will record the movement of weather fronts, thermals, and dust devils past the landing sites. Seismometers will record background noise from winds and temperature and pressure changes.

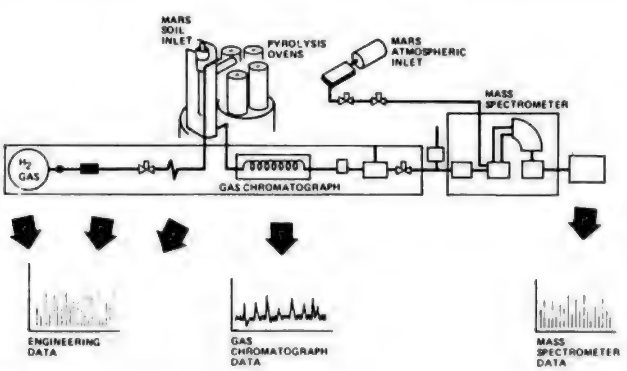
Meteorology Unit. Transducers measure temperature and pressure; anemometer measures windspeed by its cooling effect on a heated wire. Accelerometers and radar altimeter are used to determine atmospheric density and pressure from their drag on the descending lander.

Infrared Spectrometer. Detects and measures moisture in the atmosphere from the changes in solar radiation as it reflects from Martian surface through the atmosphere to the orbiter. It can detect water in amounts down to one micron.

Retarding Potential Analyzer. Measures the concentration and charge of ions and electrons in the ionosphere as they flow across the analyzer's charged grid in lander capsule.

Upper Atmosphere Mass Spectrometer. Identifies chemical content and concentrations in upper fringe of atmosphere.

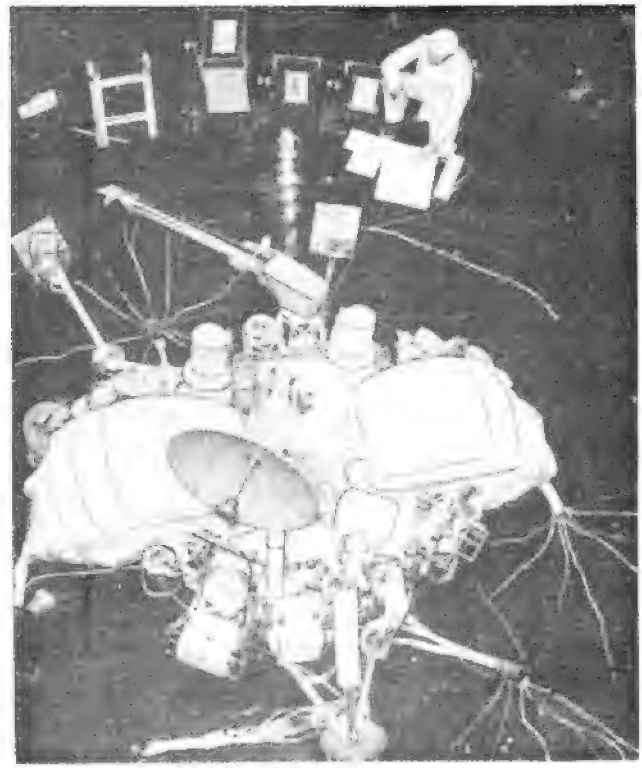
Radio, Radar Systems. S-band Earth-Mars microwave link for commands and data relay; UHF lander-orbiter links; X-band orbiter-Earth link for science use.



Gas Chromatograph Mass Spectrometer.

Major Contractors

Lander	Martin Marietta
Lander Camera	Itek
Orbiter	JPL
Orbiter Camera	Ball Brothers
Biology Instrument	TRW
Infrared Radiometer	Santa Barbara Research
X-ray Fluorescence Spectrometer	Martin Marietta
Gas Chromatograph-Mass Spectrometer	Litton
Seismometer	Bendix
Meteorology Unit	TRW
Infrared Spectrometer	JPL
Retarding Potential Analyzer	Bendix
Upper Atmosphere Mass Spectrometer	Bendix
Radio System	RCA
Radar System	Teledyne Ryan
Titan IIIE/Centaur Launch Vehicle	Martin Marietta / General Dynamics
Guidance and Control Computer	Honeywell

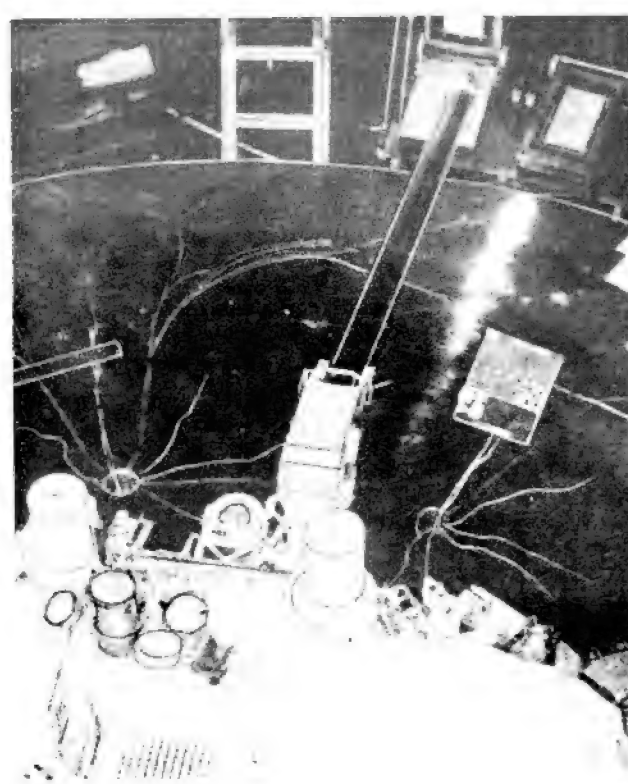


Above, three of these 18-nozzle engines will operate to bring the Viking Lander to a soft-landing on the Martian surface. They have been specially developed to disperse the blast of the exhaust which might otherwise disturb the soil beneath the Lander and compromise experiments which rely on uncontaminated surface samples.

Top right, Viking completes a month-long series of rigorous tests designed to qualify it for operating on the surface of Mars in 1976. The tests were conducted in a huge vacuum chamber at the space facilities of Martin Marietta Aerospace at Denver, Colorado.

Right, the long arm of the sampler experiment reaches out to take a bite of soil from a sample box during qualification tests at Martin Marietta. The 11 ft. (3.35 m) boom deposits the samples in three circular receptacles on the main body of the spacecraft. The soil will be analysed for chemical and mineral content, as well as evidence of biological activity.

All photos Martin Marietta Aerospace



Communicating with Viking

The Viking Lander Communications subsystem designed and built by RCA's Astro-Electronics Division of Princeton, New Jersey, consists of a relay link between the orbiter and lander and a direct link connecting the lander and Earth. Ultra-High Frequency (UHF) radio is employed to relay scientific data to the orbiter and an S-band transmitter on the lander sends data directly to Earth.

UHF Orbiter Relay Link

The relay link is the primary means of communicating during descent and landing until a direct link between the lander and Earth can be established on the surface of Mars. The UHF circuits use compartmentalized, shielded discrete-element wired circuits.

When the lander separates from the orbiter and descends into the Martian atmosphere, UHF radio will begin transmitting real-time data at 4,000 bps and at a frequency of 381 MHz to the orbiter. This information will consist of entry science data, such as the pressure and temperature of the Martian ionosphere and atmosphere, and engineering information related to the lander's operating performance.

The subsystem weighs a total of 10 lb. and has a primary power requirement of 120 watts. It utilizes split-phase pulse code modulation and frequency shift keying. A fixed, crossed-dipole antenna radiates signals to the orbiter. Any one of three power modes may be selected.

Prior to separation from the orbiter, the lander will undergo a series of system checks in the lower power mode (1 watt). During descent, the 10 watt mode will be used. After touchdown, the transmitter will be switched to 30 watts of power to handle a data stream rate of 16,000 bits per second. With successful completion of the soft-landing on Mars, the lander will continue to broadcast for about three days *via* the UHF system before switching over to the direct S-band link. Imagery showing the area surrounding the landing site as well as data received from the meteorological and biological sensors contained on the lander can then be transmitted to the orbiter for relay to Earth.

The orbiter will be able to receive this data from the lander an average of 20 minutes each pass. It will be orbiting Mars once every 24.6 hours.

S-Band Direct Link

The lander S-band link provides for direct transmission of high-volume scientific and imaging data, Doppler tracking planetary ranging and command reception. The subsystem weighs 63 lb. and has a power requirement of 113 watts. It operates at 2.2 GHz frequency and is coherently locked to Earth frequency references.

Engineering data is transmitted at a rate of 8 1/3 bits per second and scientific information may be sent at selectable rates of 250, 500 and 1,000 bits per second. Coded (32/S), phase shift keying-pulse code modulation information is received at 4 bits per second.

A 30-in. diameter parabolic reflector high-gain antenna will be used to transmit information from Mars dircetly to Earth. The high-gain antenna is steerable and utlizes a two-axis gimbal. The mast for this antenna is deployed and locked into position immediately upon landing on Mars. Powered by a d-c driven motor, the antenna is stepped to follow the Earth by an open-loop command and control system. A fixed, crossed dipole S-band low-gain antenna will receive the commands from Earth.

Redundant modulator-exciters and a 20 watt travelling wave tube amplifier transmit the telemetry and imaging data at a frequency of 2295 MHz for approximately two hours each day.

Two S-band receivers operate on the same frequency and use the same receiver selector. The receiver selector furnishes signals to the modulator-exciters and the command detectors. One of the receivers is connected to the low-gain antenna and is the primary command receiver. The other receiver is linked to the high-gain antenna to detect the ranging signal. This receiver also serves as a backup command receiver when the high-gain antenna is pointed toward Earth.

Viking Antenna

General

The RCA Viking Antennae are specially designed and built to operate in the hostile Martian environment. They must withstand harsh surface winds, sand and dust storms, low pressure, and a temperature range from +233° to -195°F.

The UHF Low Gain Antenna is 18 in. high and is located on the Viking Lander Capsule (VLC). It provides for the rapid, high volume transmission of data from the VLC to the Viking Orbiter for relay to Earth. The antenna will operate during both the descent of the VLC to the Martian surface and at programmed times during the mission after touchdown.

An insulating foam designed to minimize power disruptions during transmission in the low pressure Martian atmosphere is enclosed in cylindrical containers on the ends of the antenna elements.

UHF Low Gain Antenna Specifications:

Use:	Communications to Earth *via* Orbiter Relay.
Operation:	During Martian entry and from surface.
Type:	Crossed dipoles, circularly polarized.
Frequency:	400 MHz.
Power:	60 Watts.
Weight:	2.9 lb.

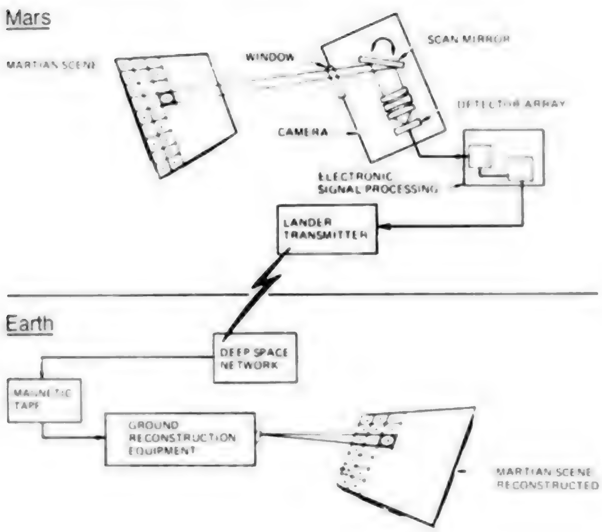
The S-Band Low Gain Antenna is 6 in. high and is also located on the VLC. It will receive signals from Earth and will operate according to the mission programme after the VLC lands on the planet's surface.

S-Band Low Gain Antenna Specifications:

Use:	Receive commands from Earth.
Operation:	Martian Surface.
Type:	Broad pattern, circularly polarized.
Frequency:	2100 MHZ.
Weight:	0.26 lb.

The S–Band High Gain Antenna has a 30 in. parabolic dish of traditional appearance. It will be used to transmit and receive radio signals between the VLC and Earth and will

Viking Picture Taking Process

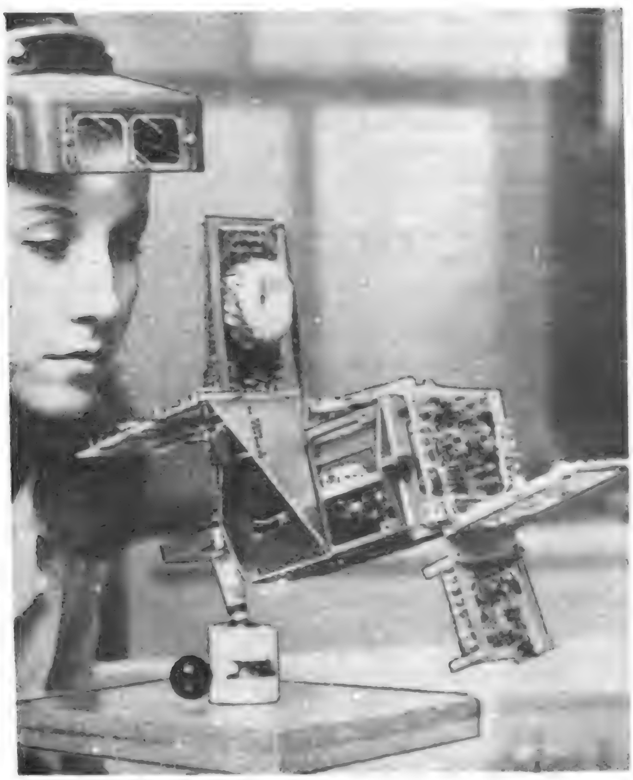


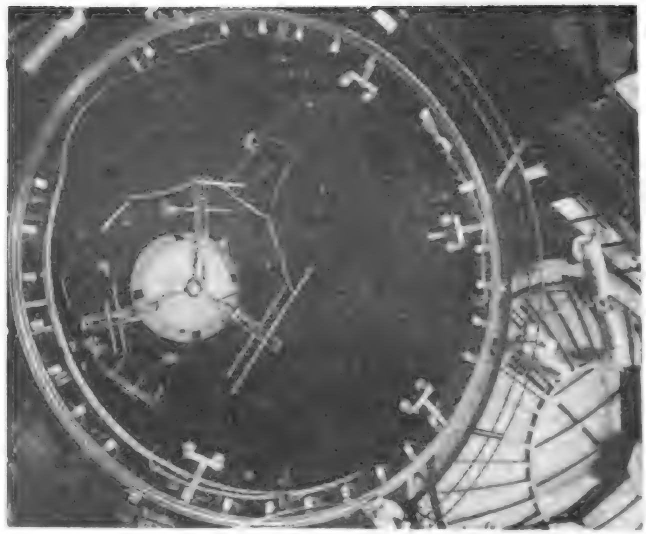
How pictures taken by the television system aboard the Viking Lander will be processed, transmitted and reconstructed on Earth.

National Aeronautics and Space Administration

Kathy Daniels of Honeywell's aerospace Division examines part of a special-purpose computer which will control experiments in the Viking Lander.

Honeywell Limited





Deep inside a space simulation chamber at Martin Marietta near Denver, Colorado, a Viking spacecraft is prepared for tests to prove its ability to make the journey to the planet Mars. The huge cover, *bottom right*, was placed on top of the 65 ft. (19.8 m) high chamber which was then pumped to a near vacuum for month-long tests during which the craft was subjected to intense temperature changes and mechanical and acoustical vibration.

All photos Martin Marietta Aerospace

S-Band High Gain Antenna Specifications:

Use:	Transmit data Mars-to-Earth.
Operation:	Martian surface.
Dish:	30 in. diameter.
Frequency:	2100-2300 HHz.
Power:	40 Watts
Pedestal:	Elevation over Azimuth.

Controller Specifications:

Use:	Pedestal drive and encoder processor.
Operation:	Martian surface.
Input:	Commands from on-board computer.
Output:	Drives pulses to two Stepper motors sine/ cosine from two Resolvers.
Weight:	0.5 lb.
Size, Max:	4 x 5 x 7 in.
Configuration:	Two 2-sided 4-layer Printed Circuit Boards.

operate after touchdown according to the mission programme. Since Mars, like Earth, rotates on its axis, it is necessary for the S-Band High Gain Antenna to be facing toward Earth for maximum effective transmission. Once the VLC has landed safely on Mars, an on-board computer will calculate the necessary alignment (both azimuth and

[Continued on page 240

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EXOBIOLOGY SENSORS

By Steven J. Hynes

Introduction

With the Viking probes of 1975 an entirely new phase of space exploration will be opened up, namely the search for life on other worlds. This search, conducted at first by mechanical devices and later by Man himself, will undoubtedly be one of the most difficult tasks ever undertaken. If successful it may bring rewards beyond imagination.

The Science in Search of a Subject

The study relating to extraterrestrial life is called exobiology and was once referred to as the science in search of a subject. Unfortunately, this is still the true state of affairs at this present time; we know of no other life forms beyond those found on Earth. Inevitably then, speculations about extraterrestrial life forms are bound to be coloured by our own limited experience. Despite this however, on Earth itself there is an incredible variety of life occupying a vast range of physical and chemical environments, and from these it is possible to determine a number of characteristics attributable to life. Which of these characteristics are universal is impossible to say but certainly they represent a starting point whence investigations of extraterrestrial life might reasonably be started and life sensing mechanisms might logically be expected to take advantage of these characteristics.

These differences between life and non-life (on Earth at least) may be summarized as follows:

1. *Nutrition* – the intake of chemicals to provide energy to enable the organism to continue to function.
2. *Respiration* – the process whereby an organism obtains energy as a result of chemical changes within itself; in terrestrial organisms this generally involves oxidation in some form.
3. *Excretion* – as a result of the chemical changes involved in respiration some toxic chemicals are usually produced by organisms and excretion is the method by which these are removed.
4. *Reproduction* – for many reasons, terrestrial organisms tend to have quite short lives (generally less than 200 years), so in order that the species can continue to exist it is necessary for the organism to copy itself periodically. This process of reproduction is also a vital factor in the evolution of life; by the pooling of genes new possibilities for increasing the efficiency (and hence the likelihood of survival) of the species are introduced.
5. *Growth* – though this is often considered to consist entirely of increase in size, biologically speaking growth also involves an increase in complexity and efficiency.
6. *Movement* – in terrestrial life forms, this characteristic is of varying importance but for higher forms of life it conveys a useful advantage in the competition for food, and also in self-preservation!
7. *Sensitivity* – this involves the response of an organism to a stimulus. The stimulus need not necessarily be "direct", such as pain in an animal, but may include gravity, light or the chemical environment, for example.

These characteristics are very general in nature and cover millions of chemical reactions which occur within terrestrial organisms. Identification of some of the chemicals involved in these reactions may also provide strong evidence of life.

Chemicals of Life

The most important chemicals on which terrestrial life forms are based are called proteins and nucleic acids. Proteins are constructed from amino acids which are arranged into long chains, the arrangement of the amino acids in the chain determining the type of protein formed and its function. They form the basic mechanical structure of cells and also perform specific actions, such as catalysis of biochemical reactions; in this role they are called enzymes.

Without enzymes life in its present form would not be able to exist because the chemical reactions which support life would occur too slowly. Nucleic acids are important because of the part they play in cell reproduction; the two types of nucleic acid are DNA (deoxyribonucleic acid), and RNA (ribonucleic acid), DNA being perhaps the most widely discussed. It consists of strands of alternate sugar and phosphate groups linked by side groups, the whole arrangement then being twisted producing the famous "double helix" configuration. The side groups may be of Thymine, Adenine, Cytosine or Guanine and the chemical structure of these is such that Thymine will form a stable link with Adenine and Cytosine with Guanine; no other arrangement is possible. During cell replication the two strands of DNA unwind and link up with free units (consisting of a sugar and phosphate group with a single side group), each side group in the single strand linking with its free unit complement. RNA consists of single strands built in the same way as those of DNA except that Uracil replaces Thymine, both chemicals having a similar molecular structure. The function of RNA is to construct proteins from the instructions contained in the DNA arrangement. If extraterrestrial organisms work in a similar manner to those with which we are familiar (which as we have said is an extremely dangerous assumption), detection of proteins and nucleic acids in samples would be convincing evidence of the existence of life.

Additional evidence for life may be obtained by identifying the chemical ATP, Adenosine Triphosphate. During metabolism an organism often finds itself with excess energy to spare or deficient in energy and since it is generally desirable to maintain an "energy balance" obviously some method of storing energy for quick release is needed. Storing chemical energy is a function of the chemical ATP (Fig. 1); here energy is stored in the bonds connecting the phosphates and is released by the process of hydrolysis to produce firstly ADP (adenosine diphosphate) with the release of 33.4 kJ of energy, then AMP (adenosine monophosphate) with the release of a similar amount of energy. AMP is a relatively energy poor compound and further hydrolysis will yield only 12.5 kJ of energy. As used by terrestrial organisms, ATP is

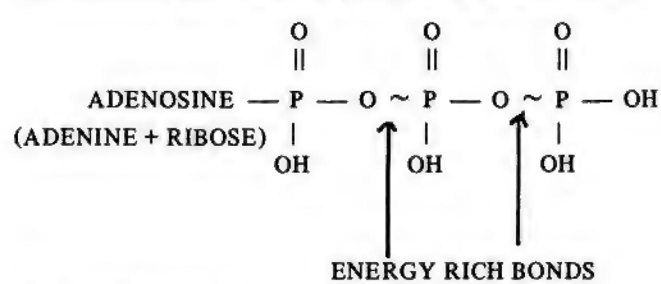

Fig. 1. ATP molecule.

involved in such vital life processes as the breakdown of glucose, fatty acids and amino acids and in the transport of substances in and out of cells, all reactions where energy is needed.

One other feature of living things is worthy of mention and that is that the molecules of amino acids tend to have either a "right-handed" or a "left-handed" structure and the two are mutually incompatible so that one could expect to find molecules of only one of these types. On Earth for example all are "left-handed" or L-amino acids but they might just as well be "right handed" or D-amino acids. This kind of activity is determined by the direction in which the molecules rotate polarized light, whether to the right or left.

What of the other characteristics described? How are they to be determined? And what is likely to be the most effective method of identifying life? There are no easy answers unless an alien life form obligingly waves in front of the camera of our spaceprobe; but since, in our Solar System at least, all we can hope to find is microscopic life forms, more devious methods must be employed.

Sampling Techniques

Looking through the list of general characteristics of life several possibles are apparent, for example, growth and reproduction. If a sample of a planet's soil is injected into a growth medium and light passed through the medium, the light will be dimmed if any organisms in the sample reproduce in the medium, as the medium will tend to become cloudy (turbid). This is the principle of the famous "Wolf Trap", named after the famous Prof. Wolf Vishniac, who was so tragically killed whilst on an expedition in Antarctica recently. Of course, it may be that any organisms on the planet will be unable to metabolise the nutritive substances we have provided being accustomed to an entirely different kind of diet, and indeed, they may even find the growth medium toxic. Yet again, the increase in turbidity may be due to some unforseen inorganic process, so in his apparatus, Vishniac incorporated a device to measure the pH of the environment, continuous changes in which would count toward confirming that the change of turbidity was indeed due to living organisms.

On a planet such as Mars, the medium chosen would of course have to be one in which anaerobic growth (that is, without oxygen) is possible, because that planet has little free oxygen, a large part of its tenuous atmosphere being made up of carbon dioxide. Fortunately, we do have some experience of anaerobic organisms on Earth, which may turn out to be quite useful.

Still considering the Martian environment, if there is sufficient water available, it may be that organisms may feed by means of photo synthesis. The reactions involved in photosynthesis can be summarized by the equation:

$$6CO_2 + 6H_2O + \underset{\text{(from sunlight)}}{2830\text{ kJ}} \longrightarrow C_6H_{12}O_6 + 6O_2$$

This assimilation of simple compounds into the more complex sugar (glucose) is achieved through the agency of chlorophyll (a complex compound related to haemoglobin); but this compound might not be available on Mars and it is not certain whether the process of photosynthesis can occur. It is of course possible that there may be some alternative agent. Assuming that photosynthesis does occur, how might it be detected? Most elements occur in more than one form, differing in the number of neutrons in the nucleus of their atoms. In the element Carbon, for example, the normal type has an atomic weight of 12; however, the alternate form (the isotope) has an atomic weight of 14. Carbon 14 is radioactive and its presence can be determined by a Geiger-Mueller counter. If radioactive carbon is used in the carbon dioxide it may be possible to trace its path through organic reactions.

A device to detect this might work as follows: a sample of soil which may contain life forms is placed in a reaction vessel with some of the "labelled" CO_2; an energy source is allowed so that, with water also present, photosynthesis should occur if it is possible. Allowing for sufficient time for the reaction to proceed, the atmosphere is flushed out and the sample heated. If any of the radioactive carbon is left in the system it is very likely that this will be due to its presence in carbohydrates such as glucose, because the carbon dioxide has been removed from the system. This is a quite convincing test for the existence of life and something of a similar nature is being included in the Viking project.

A similar test can be made to show respiration, although in this case, the process is effectively reversed. It also has the disadvantage of requiring an atmosphere which includes free oxygen. The reaction for respiration is summarized thus:

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + 2830\text{ kJ}$$

Detection of this reaction can be achieved in three ways, either the carbohydrate can be labelled by using Carbon 14 in a similar way to the photosynthesis method or the increase in water vapour content of the atmosphere may be used or the rise in temperature because of the energy released. To complement the photosynthesis experiment, this respiration experiment is also being carried by Viking, again using the Carbon 14 system of detection.

Specific chemicals common to terrestrial life forms may also be tested for by means of spectrometry, comparing the absorption lines of the elements with standard spectra obtained on Earth. They may also be detected by testing if the soil samples react with chemicals known to produce a certain reaction with a specific organic compound. For example, identification of certain types of enzyme would be excellent evidence of life; phosphatase is perhaps one of the better choices here, being quite common in many terrestrial organisms.

A remote controlled microscope with a television attachment may also be a useful addition to the range of life detection devices but this would be best used in conjunction with other apparatus rather than in place of it. It is not unknown that inorganic objects show a structure resembling that of living things and this may cause considerable confusion, if there was no other way of corroborating the observations.

The Unforeseeable

By definition, no one can foresee the unforeseeable and the intricacies of life are so great that it is almost impossible to allow for the existence of life forms whose structure and biochemical processes are unlike those on Earth; so, as was stated earlier, the detection of life on other worlds at the first attempt is likely to be met with failure, if only because we are not sure what to look for. I strongly suspect, however, that over the years and centuries of the growing maturity of

[Concluded on page 240

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DID LIFE COME FROM OUTER SPACE?*

A reply to Professor Francis Crick from Academician A. I. Oparin.

One of the major benefits of the quest for evidence of extra-terrestrial life is the fresh light it may throw on the beginnings of life on Earth. Does life – and intelligence – emerge in the Universe wherever conditions are favourable? Or is the human family the product of some rare cosmic accident? If micro-organisms, unique to Mars, are detected by the Viking Landers, Science will have unique material for analysis. But would even this momentus discovery settle all questions of life's origin?

Some scientists believe that life was brought to our planet by means of spores travelling through stellar expanses. Over the years this hypothesis has undergone various changes, and certain scientists think that life was even implanted here deliberately by some highly developed civilisation on another planet.

The British scientist Francis Crick has advanced a number of new points intended to support this assumption. He draws attention to the considerable role played by molybdenum in metabolic processes in terrestrial organisms, and points out that only comparatively small quantities of this metal are present in the Earth's crust. At the same time there are stellar systems with quite a large molybdenum content. Possibly the "cosmic seeding" was done from molybdenum stars.

He also refers to the universality of the genetic code of all living terrestrial organisms. If it is assumed that life on Earth originated independently and simultaneously in different places, then the existence of this single hereditary mechanism for the whole planet remains a mystery which, he claims, is not the case if the hypothesis that life was brought from other planets is accepted.

Writing in the Moscow newspaper *Socialist Industry* Academician Oparin has this to say:

The origin of life is one of the greatest philosophical problems of the natural sciences. Until it is solved an understanding of the very essence of life remains beyond our intellect. However fully and profoundly we may comprehend the substances, structure and processes forming the basis of the organisation of living bodies today, we are not in a position to answer the question: why are they organised in precisely the way they are? This can be understood only on a historical basis, in the light of an understanding of how life was established and how it developed.

Darwin's theory provided a rational explanation of how the multiformity of life in our time arose from extremely simple organisms, from which all life on Earth sprang. But the origin of these primeval creatures remained an open question, and so the whole harmonious system of biological evolution was deprived of a foundation, and people were left with a sense of disappointment and dissatisfaction.

In the mid-nineteenth century attempts were made to solve the problem of the origin of life on the basis of a study of "spontaneous generation", that is the sudden origination of microbes in various putrefying infusions and broths. But Pasteur's brilliant experiments showed that there was no question of life originating here. The microbes found in the liquids were reproduced by living creatures similar to themselves.

Pasteur himself, of course, never claimed that abiogenesis, the evolution of life from inert matter, was impossible. But many of his contemporaries interpreted his experiments in precisely this sense, as proof that it was impossible for life to originate anywhere, at any time. They took the view that the sources of all living things did not come into being independently on our planet but were brought to Earth from other worlds, from "eternal plantations of life".

More than a century ago efforts were made to find some authentic signs that living organisms or the remains of such organisms had been brought to the Earth from outer space. But all such attempts seem futile even now that man has penetrated so far into space. Apart from the complete absence of factual evidence, the idea that life was brought from outside is fundamentally incapable of providing an answer to the question of how and why the organisation of life as we know it today arose. As Bernal pointed out, this hypothesis is only an intellectual subterfuge in order to evade answering the question of how life originated.

Such a hypothesis is at variance with the theory of the evolutionary origin of life, which is seen as the result of the consistent development of increasingly complicated forms of organisation of carbon compounds. The initial elements of such a chemical evolution, still existing at molecular level, can be found in outer space. Their subsequent evolution in the atmosphere, the lithosphere and the hydrosphere can to a certain extent be followed on the basis of geological and pre-Cambriapaleontological evidence, and also of experiments with models which reproduce the transition to such evolution from the chemical and biochemical stage.

Today, as a result of a great deal of research done by scientists in various fields in many countries, it has been possible to accumulate solid factual material indicating how matter evolved and how this led to the first, most primitive organisms on our planet. This evidence will inevitably grow, and bring us increasingly to a correct, scientific understanding of the origin of life.

Let us now take a look at the "evidence" advanced by Francis Crick in support of his hypothesis that life comes from other planets.

The scientist's reference to the incompatibility between the content of molybdenum in the Earth's crust and its role in metabolism is not at all convincing. A discrepancy of this kind is by no means an exception but is a widespread rule applying to a number of elements, and it can be fully explained from the evolutionary point of view. So it is quite unnecessary to drag "molybdenum stars" into a solution of our problem.

In just the same way natural selection, which is one of the main factors of biological evolution even in its very early stages, provides us with a completely rational explanation of the present universality of the genetic code. Over the millennia such selection has led to the destruction of variants which are increasingly imperfect from the standpoint of selection.

One can, of course, dream about life being sent from other worlds to our own by some extra-terrestrial intellect. But if one were to allow for a minute that such a fantastic happening really could have taken place, such an assumption would contribute nothing to the solution of our problem. For even so, life must have originated in an evolutionary way somewhere, at sometime, and the Earth – as modern scientific evidence has shown – is the most suitable place for this.

* *Supplied by the Novosti Press Agency.*

SATELLITE DIGEST – 83

A monthly listing of all known artificial satellites and spacecraft, compiled by Robert D. Christy. Information is based on that supplied by the Space Department of the Royal Aircraft Establishment, Farnborough and other sources. For information on the derivation of orbital parameters, abbreviations, etc., see July 1972 issue, p. 262.

Continued from May issue, p. 200]

Name, designation	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclin-ation (deg)	Nodal period (min)	Launch centre, launch vehicle and payload/launch origin
Soyuz 16 1974-96A	1974 Dec 2.40 5.94 days (R) 1974 Dec 8.34	Sphere + cone-cylinder + 2 wings + antennae, 6680	7.5 long 2.2 dia	184 183 225	291 210 226	51.80 51.80 51.80	89.19 88.37 88.95	Tyuratam-Baikonur Soyuz USSR/USSR (1)
Helios 1 1974-97A	1974 Dec 10.30	Double cone + antennae 350	2.77 max dia 2.18 long	Heliocentric orbit				ETR Titan-Centaur FRG/NASA (2)
Cosmos 697 1974-98A	1974 Dec 13.57 11.6 days (R) 1974 Dec 25.2	Sphere-cylinder 4000?	5 long? 2 dia?	174	392	62.80	90.16	Plesetsk USSR/USSR
1974-98D	1974 Dec 13.57 13 days 1974 Dec 26	Sphere?	2 dia?	177	360	62.80	89.86	Plesetsk USSR/USSR (3)
Meteor 20 1974-99A	1974 Dec 17.49 500 years	Cylinder + 2 vanes	5 long? 1.5 dia	842	897	81.24	102.38	Plesetsk USSR/USSR
Cosmos 698 1974-100A	1974 Dec 18.59 8 years	Cylinder + paddles?	2 long? 1 dia?	515	552	74.04	95.32	Plesetsk USSR/USSR
Symphonie 1 1974-101A	1974 Dec 19.11 indefinite	Octagon + 3 paddles 221	0.5 long 1.85 dia	395 38705	38500 40919	13.23 1.18	688.4 1646.6	ETR Thor Delta FRG & France/NASA (4)
Molniya-2L 1974-102A	1974 Dec 21.10 5 years?	Cylinder-cone + 6 panels + 2 antennae 1250?	4.2 long? 1.6 dia?	659 611	40629 39771	62.90 62.87	736.77 718.28	Plesetsk USSR/USSR (5)
Cosmos 699 1974-103A	1974 Dec 24.46 5 years	Cylinder?		114 428	418 440	64.99 65.03	89.80 93.31	Tyuratam-Baikonur USSR/USSR (6)
Salyut 4 1974-104A	1974 Dec 26.18 9 months?	Stepped cylinder + 3 panels 18500	12 long 4.15 max dia 2.0 min dia	212 276 336	251 341 349	51.57 51.57 51.58	89.08 90.65 91.32	Tyuratam-Baikonur Proton USSR/USSR (7)
Cosmos 700 1974-105A	1974 Dec 26.50 1200 years	Cylinder?	1.3 long? 1.9 dia?	966	999	82.96	104.80	Plesetsk USSR/USSR
Cosmos 701 1974-106A	1974 Dec 27.38 12.9 days (R) 1975 Jan 9.3	Sphere-cylinder 4000?	5 long? 2 dia?	205 170	319 314	71.39 71.38	89.77 89.37	Tyuratam-Baikonur USSR/USSR (8)

Supplementary Notes:

(1) Manned spacecraft carrying cosmonauts Anatoli Filipchenko and Nikolai Rukavishnikov on a mission designed to simulate the forthcoming Apollo-Soyuz Test Project flight. In-flight experiments included the use of a docking simulator. Orbital data at 1974 Dec 2.6, 1974 Dec 3.1 and 1974 Dec 5.3.

(2) German-built solar probe originally scheduled for launch two days earlier; the delay was caused by a faulty pump in the upper stage of the launch vehicle. Experiments include measurements of the solar wind, magnetic fields, cosmic rays, micrometers and the zodiacal light.

(3) Elected from 1974-98A 1974 Dec 24.

(4) European-built communications satellite; launch was delayed from 1974 Dec 17 owing to fuel spillage from the launch vehicle's second stage.

(5) Orbital data at 1974 Dec 23.2 and 1974 Dec 26.2.

(6) Orbital data at 1974 Dec 24.5 and 1974 Dec 26.1.

(7) Soviet manned space station, the first crew being carried by Soyuz 17 (see next month's table). Orbital data at 1974 Dec 27.0, 1974 Dec 30.2, and 1975 Jan 17.4.

(8) Orbital data at 1974 Dec 28.0 and 1974 Dec 29.3.

SSME MATERIALS TESTED

Testing of materials to be used in the liner of the Space Shuttle's main engines has begun at the Marshall Space Flight Center. Using liquid hydrogen and chlorine tri-fluoride, the first ignition of a 50,000 lb. thrust test engine pre-burner was achieved successfully at reduced pressure. Pressure will be increased gradually in each of a series of firings until full-thrust, full-pressure tests are achieved.

SPACE REPORT

A regular monthly review of Space Events and Technical Trends

WORLD'S LARGEST TELESCOPE

On Seven Springs Mountain near the village of Zelenchukskaya in the Northern Caucasus Soviet astronomers have begun a long "running in" programme to bring the world's largest optical telescope to optimum working conditions. When fully operational the range of the new 236 in. (605 cm) reflector will be half as far again as the famous 200 in. (500 cm) Palomar giant in California. It will be able to detect stars as faint as magnitude 26 and 27.

Preliminary details of the telescope were given in our article "Opening the Far Frontier" (*Spaceflight*, February 1975 pp. 51-54). These photographs specially obtained for us from Moscow show the Observatory as it appears today.

According to the chief designer Dr. Bagrat Ioannisiani, "studies will be concerned with the structure, physical nature and evolution of extra-galactic objects, and detailed investigations of the physical properties and chemical composition of peculiar, rotating and magnetic stars.

"The telescope will also help to obtain information for the study of processes involved in star formation and evolution, for examining the surfaces and chemical composition of atmospheres of the planets, for trajectory measurements of 'artificial celestial bodies' at long distances from the Earth, and for many other tasks."

Sectional model of the Observatory showing the telescope's alt-azimuth mounting.

Below, approach road to the Astrophysical Observatory of the USSR Academy of Sciences which contains the 236 in. (605 cm) reflector. The telescope is situated at an altitude of 2,170 metres beneath pollution-free skies and far from city lights in the spurs of the Caucasus. *Right*, interior of the Observatory.

All photos Novosti Press Agency

Cornell University Photo by Russ Hamilton

Aerial view of the radio telescope near Arecibo, Puerto Rico, showing the 1,000 ft. dish reflector which has been modified to achieve greater sensitivity. (Compare with photo p. 53, *Spaceflight*, February 1975). The original wire-mesh reflecting surface has been replaced by 38,778 perforated panels affixed to steel support cables which maintain the overall spherical shape of the dish to within 1/8th inch – a tenfold improvement over the steel-mesh surface. The Arecibo Observatory is a part of the National Astronomy and Ionospheric Center, a national centre operated by Cornell University under contract from the National Science Foundation.

ARECIBO TELESCOPE IMPROVED

The 1,000 ft. diameter radio telescope at Arecibo, Puerto Rico has recently been returned to full operation after an improvement programme which has lasted almost a year.

The original surface of the telescope's reflector was made from a loosely woven mesh surface covered with perforated aluminium panels. These reflected the shorter radio wavelengths and limited the operation of the instrument to the larger wavelengths in the radio spectrum.

The reflector has now been resurfaced with almost 39,000 panels of aluminium sheet, each one measuring one metre by two metres. These panels are supported by the cables above them, and these cables are themselves supported by 29 lower prestressed cables. This type of construction limits the effects of thermal sagging of the surface to less than one sixteenth of that experienced by the original reflector. The panels form a reflecting surface which is never distorted from a perfect sphere by more than one eigth of an inch at any point.

The individual panels are kept in alignment by the use of a laser system which surveys small white vinyl targets which are mounted on one corner of each panel. The panels themselves are perforated by small holes, to help ensure the maximum stability of the instrument as a whole. The holes allow about 40% of the incident sunlight to penetrate to the ground beneath. This allows healthy vegetation growth which is used to control soil erosion under the telescope.

ALSEP IS FIVE YEARS OLD

In November 1969 two American astronauts placed and left on the Moon's (Ocean of Storms) a remote scientific instrument package. Five and a quarter years and over 21,000 Earth-to-Moon commands later this set of instruments continues to radio back to Earth information about the Moon's seismic activity, the energy hitting the surface from the Sun and the Moon's weak magnetic field.

Original specifications for the Apollo Lunar Scientific Experiment Package (ALSEP 21) called for the instruments to last for one year after the return of Apollo 12 astronauts Pete Conrad, Alan Bean and Richard Gordon.

Don Wiseman, one of the men originally responsible for the hardware development at NASA's Johnson Space Center (JSC), Houston, attributes the long life to basically simple design with basically durable materials. "It was a bare bones design; basically sound," he said.

According to W. "Ike" Eichelman, JSC's chief technical monitor for the ALSEP, the basic ingredient in the longevity of the instrument packages is their atomic power plants. Due to several factors – the Moon's environment, the cosmic irradiation, and others – the generating units have actually performed better on the Moon than ever predicted using simulated environments on Earth. Eichelman estimates that ALSEP 12 will last at least two more years, or seven times longer than its original life expectancy.

The need for remote data from the Moon centred about

certain questions best answered with continuing data from which a trend could be established; questions like what is the Moon's internal structure and temperature, what processes are responsible for the present structure of the lunar surface, what is the pattern and distribution of seismic activity on the Moon, how do solid body properties and processes on the Moon compare with those on Earth?

The ALSEP series which included similar packages for Apollo missions 14, 15, 16 and 17, was designed to return lunar scientific data to Earth in the areas of geology, geophysics, geochemistry and astrophysics.

Each ALSEP was carried to the Moon in two compartments aboard the Lunar Modules and placed in position by the astronauts during their forays about the Moon's surface. Although each ALSEP contained a number of identical instruments, each one was different in distinct ways from the others. Each, however, was powered by a Radioisotope Thermal Generator (RTG) which transforms atomically generated heat into about 75 watts of energy at 16 volts.

The instruments consisted of a passive seismic device, an active seismic array using mortar rounds to set up shock waves, two ion detectors, a solar wind spectrometer, a particle detector, magnetometers and instruments to measure heat flow from the Moon's interior.

Dr. Palmer Dyal, a NASA lunar investigator at Ames Research Center in California, has derived measurements of the Moon's magnetic field from the Apollo ALSEP magnetometers. His estimates show the Moon's magnetic field to be about 1,000 times weaker than the Earth's and the result of a probable one-time magnetism. No significant dipole field exists on the Moon at present – which means a magnetic compass would be absolutely useless. The Earth's field, in contrast, derives from internal processes.

A powerful magnetic field is generated deep within the Earth by the constantly rotating molten metal core. This core functions like a dynamo and develops a field measurable many thousand miles into space. In contrast, the main lunar magnetic field consists of near-surface fields highly variable in magnitude and direction.

Dyal says "that the lunar magnetic field can be viewed as a sort of magnetic tape recording of conditions on the Moon more than three thousand million years ago." These investigations have also led to other tentative conclusions concerning the interior structure of the Moon. From magnetic data Dyal has figured the abundance of free iron on the Moon at about 2.5 per cent by weight. Total iron content of the Moon is about nine per cent by weight. The Earth is about 30 per cent iron by weight.

Signals received by the seismometers have definitely established the existence of Moonquakes. These are associated with activity deep within the Moon 420 to 720 miles (700 to 1,200 km) and with shallow activity produced by thermal heating and cooling during the lunar day and night. A third class of seismic events may be associated with processes within the lunar regolith.

One of the most surprising results was the long duration and ringing nature of seismic signals from the Moon – completely different from that observed here on Earth. This is explained by the diffusive propagation of the shock waves as a result of intense scattering, particularly near the lunar surface. The diffusion is enhanced by low attenuation due to the lack of water and other volatiles in the pores of the lunar rocks. For this reason, seismic studies based on reflected signals cannot be used to the same advantage on the Moon as they are on Earth.

Other important findings based on the seismic data are that the lithosphere (solid part) of the Moon is 420 to 720 miles (700 to 1,200 km) thick, much thicker than the Earth's. The Moon's core is probably near the melting point. Scientists, however, are waiting for a large meteorite impact similar to one which occurred over two years ago to confirm their theories about the Moon's core.

Seismic energy of the Moon has been found to be about 10 orders of magnitude less than the Earth's, and due to the Moon's thick lithosphere, there is no crustal plate movement like on Earth.

The heat flow measured by ALSEP instruments was surprising. It is about half that of the Earth's. It places strong constraints on the radioactivity of the Moon and indicates differentiation and upward concentrations of radioactivity early in the Moon's history. Previous models of the Moon's radioactivity were based on chondritic meteorites and terrestrial rocks. Bulk radioactive concentrations consistent with the heat flow measured on the Moon indicate that those models are inaccurate. Other findings indicate that, in comparison to the Earth, the Moon is depleted in volatile elements like iron, sodium and potassium.

Seismic, magnetic and heat flow data from the ALSEP's indicate a differentiated Moon well along in its evolutionary history – further along than the Earth.

The ALSEP instruments have also been successful in obtaining a better picture of the Earth's magnetosphere, a region of trapped particles. As the Earth orbits about the Sun it is continually in the flux of high energy particles emitted by the Sun. When these particles approach the Earth's magnetic field they are deflected outward further into space. By using information from the suprathermal ion detector, cold-cathode ion gauge and solar wind spectrometer, scientists have been able to look at Earth's solar atmosphere with more precision than ever.

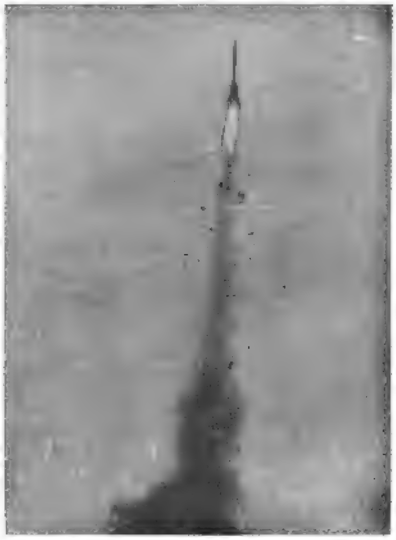
One of the striking results has been the discovery that solar particles exist in stronger concentrations on the Earth's anti-Sun side than had been predicted. The implications and mechanism for this interesting turn are not yet known.

Data from the five ALSEP's is received by NASA's tracking network 24 hours a day. Information is stored on computer tapes and mailed to the Johnson Space Center. The computer tapes are duplicated and sent along to the dozen principal investigators still analyzing the data. Through the National Space Science Data Center data tapes are made available to the scientific community at large. Several times each week, NASA engineers and technicians monitor the ALSEP instruments "live" from the Moon looking for problem areas or performing general maintenance checks.

MORE PETRELS AND SKUAS

British sounding rockets are again making news, scoring high marks in performance and economy of operation. Bristol Aerojet of Banwell, Weston-Super-Mare, recently announced the successful firing of the 100th Petrel rocket from the Hebrides Range. A total of 144 Petrels have now been fired, not counting targets, but including those from Andoya, Thumba, Søndre Strømfjord, Kiruna and Arenosillo.

Problems relating to the temperature limits of Petrel rockets (usually 10°C to 35°C or -5° to +20°C) have it seems been exaggerated in the past, and when transporting by air



Left, Skua 4 with boost carriage (centre Chick motor not installed), and *right*, a typical launch. Launch velocity is so high that wind has very little effect on the trajectory as demonstrated by the Max Planck firings at Aeronosillo, Spain. Viewed from above none of these deviated more than 5 deg from the line of fire although the launcher was set 85 deg from the horizontal. The boost carriage for Skua 4 is the same as that for the Petrel with a new adapter on the front; the boost parachutes have a built-in two second delay and the boost carriage travels to a height of about 450 ft. taking about 20 seconds to descend.

Bristol Aerojet

no serious difficulties have been encountered. For instance, about 100 Petrel "targets" have been fired in Australia and these were propellent-filled for a temperature of +15° to +40° C; these rockets were shipped by road from Salisbury to Woomera, mainly in summer, in non-air conditioned trucks. At the end of a subsequent period of storage all of them were fired satisfactorily. On the other hand, at very low temperatures in Greenland, using the heated launcher tube, there has been no trouble with the Petrels and all four of the UK shots were successful.

A total of 25 different scientific payloads, prepared by almost as many research institutes and universities, have used Petrel as a "workhorse" and the 100th rocket (by a matter of seconds) was a successful flight of the mass-spectrometer developed by the Max Planck Institut of Heidleberg, quite a milestone. Simultaneously with this flight, we understand, another Petrel fired from a nearby launcher was in the air, for the Appleton Laboratory, measuring a wide range of ionisation and ionising radiation in the 'D' region.

Another Petrel fired in Spain with a very long payload (1.67 metres), which was also oversize on diameter and fitted with "drag buttons," flew to the required height of 85 km; the experimenter wanted to achieve this height within a tolerance of ± 2 km and special steps were taken to measure the motor batch performance, and in the event the specified altitude was achieved with slightly less than a +2 km error.

A Petrel 2 rocket has now been flown and this adds 30 km to the apogee performance of Petrel *without significantly increasing the cost.*

In addition to Petrels, there are now Skua Marks 1, 2 and 4, and they give the following performances: Mark 1 - 7 kg to 70 km altitude; Mark 2 - 7 kg to 90 km, and Mark 4 - 7 kg to 124 km. All these except the Mark 4 can be flown with lighter payloads to greater heights.

To date eight Max Planck Skua Mark 4's have been fired, and whilst from the performance point of view they have all been satisfactory, there has been a payload problem associated with vibration in the launcher; this has been corrected by improving the fit between the boost assembly and the launch tube. The Skua 4 has a very small dispersion circle as its launch velocity is 200 m/sec. The standard version is called "The Fledermaus" and for this one can contact the Max Planck Institut of Lindau, West Germany, who are the developers and main users.

The first prototype "Flamenco" 25 cm diameter rocket was test flown at Arenosillo on 9 October 1974. This flight was successful and telemetry results were good, and amongst other valuable data they indicated very low lateral accelerations. Performance was about right, and this was expected to be confirmed by the second and third prototypes. The motors, developed from well established units, are filled with British plastic propellent. Six Flamenco rockets (Fulmar is the British name) are being ordered by the Science Research Council in the UK, and fitted with separating nose shells, these will be fired at Andoya in the winter of 1976. Flamenco can carry a 40 kg payload to over 330 km altitude, and it is fired at present from either a modified Nike launcher or the existing MAN launcher.

The name of the second stage of the Flamenco rocket – fired by itself with a small boost – is "Flamenquito." There is no British version as there is no immediate requirement for heavy payloads to low apogees.

'Mother and daughter' concepts and separating payloads to put up two payloads at different levels with the same rocket are being studied. Bristol Aerojet are seeking information from experimenters on their requirements in this field.

A late report suggests that another Petrel Launcher may be installed at Aberporth, making two in all, operational in 1976. The fibreglass type launcher with remotely operated door has been installed at Arenosillo. There are now about 11 operational Petrel/Skua launchers.

ASTP CRYSTALS EXPERIMENT

Experiments designed to study growing large crystals in space will be conducted during the joint Soviet/U.S. ASTP mission this summer. American astronauts and Soviet cosmonauts plan to demonstrate to the world that spacecraft manufactured and launched by two different nations can rendezvous and dock in space and their crews can communicate, using each other's language to successfully complete the joint mission.

The crystal-growing experiment is designed to demonstrate a technique that holds promise in improving communi-

cations on the ground.

The experiment, called MA-028 Crystal Growth in Zero Gravity by NASA, is designed to find out if large, defect-free crystals can be grown in space. Crystals are used in the semiconductor electronics industry for such purposes as radio, television and other communications.

Results of a similar experiment conducted on the Skylab missions in 1973 and 1974 indicate that space-grown crystals are superior to those grown on the ground.

The experiment consists of six transparent tubes, each of which contains three compartments. The outer two compartments will contain different salt solutions which, when mixed, form an insoluble-compound – the compound which will grow into a crystal. The centre compartment contains pure water and, depending on the crystal to be grown, possibly a small seed crystal. During the experiment, the outer compartments will be opened to allow the salt solutions to diffuse toward each other and mix in the centre compartment.

Principal Investigator for this experiment is Dr. M. D. Lind of Rockwell International's Space Center in California.

AFRICAN LANDSAT STATION

Zaire will build the first ground station in Africa designed to receive Earth resources data directly from NASA's LANDSAT's under an agreement announced on 26 January in Washington, D.C. LANDSAT was originally called the Earth Resources Technology Satellite (ERTS).

The new ground station, to be built by ERTS-Zaire near Kinshasa, will be able to obtain data from LANDSAT's 1 and 2 as they pass within 1,800 miles (3,000 km) of Zaire's capital city.

Data from this area, which includes most of the African continent from the northern border of Chad to South Africa and from Kenya to the Ivory Coast, currently must be stored on LANDSAT 2 magnetic tape recorders for transmission to ground stations in the United States.

Although Zaire is the first African nation to plan its own LANDSAT station, 13 African nations and two international organizations have undertaken Earth resources investigations using data of Africa provided by NASA from the two LANDSATS. Scientists conducting these investigations are from Botswana, the Central African Republic, Ethiopia, Gabon, Guinea, Kenya, Lesotho, Libya, Mali, Nigeria, South Africa, and Swaziland. The United Nation's Food and Agriculture Organization and the Liptako-Gourma Authority are also pursuing studies based on satellite data acquired over Nigeria, Upper Volta, and Niger.

Zaire's new station will be able to produce both computer tapes and photographic imagery using data transmitted by the satellite. Under the memorandum of understanding ERTS-Zaire will make copies of LANDSAT data available to NASA as well as to scientists and others requesting data of the region.

Ground stations are already in operation outside the U.S. at Prince Albert, Canada, and Cuiaba, Brazil. Italy and Iran have agreed in the past year to build their own LANDSAT stations able to provide coverage of several African nations along the Mediterranean and Red Seas. Canada has also announced plans to build a second LANDSAT station near St. Johns, Newfoundland.

U.S. ground stations for LANDSAT are located at Fairbanks, Alaska; Goldstone, California, and at NASA's Goddard Space Flight Center in Greenbelt, Maryland.

LANDSAT 1, launched in July 1972, continues to return data while within range of ground stations. Tape recorders aboard the spacecraft are, however, no longer operable. An identical satellite, LANDSAT 2, was launched on 22 January 1975 and is now returning data from around the world.

NASA has provided Earth resources satellite data to several hundred scientists in the U.S. and more than 50 foreign countries in a programme to demonstrate the satellite's usefulness.

Developing nations have found satellite data particularly valuable in learning about their natural resources, mapping geological and man-made features and conducting agricultural research. More than 120,000 separate views of the Earth from NASA LANDSAT's have been provided to the Department of Interior's Earth Resources Observation System Data Center in Sioux Falls, S.D., where both independent scientists and the general public may obtain material for the cost of reproduction.

SIBERIAN METEORITE

Workmen clearing a stream at Chukotka in north-east Siberia have recovered an iron meteorite weighing 2,276 grams. It is notable for its lamellar (thin plate or scale) structure. Easily discernible behind a layer of oxides are interleaved laminae and crystals two to three millimetres thick.

Geologists have determined that about 90 per cent of the meteorite is iron and the rest nickel and cobalt. They are now trying to discover the meteorite's age, the history of its formation and the speed at which it encountered the Earth.

The meteorite has been taken to the USSR Academy of Sciences' meteorite committee. It is the 148th specimen in the Academy's collection.

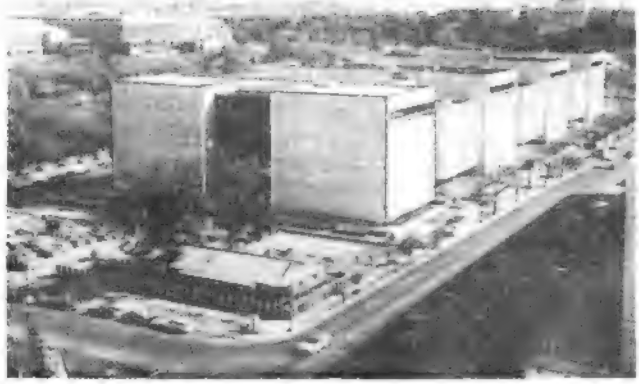
SPECULATING ON MAN'S NEIGHBOURS

By Dave Dooling

Introduction

The possibility that Man is not alone in the Universe is the subject of a fascinating, far ranging exhibit at the National Air & Space Museum in Washington, D.C. Since its opening, "Life In The Universe" has proved to be the most popular challenge to the mind ever offered by NASM.

According to NASM Director Michael Collins, the exhibit is a "summing up of what is known today about the Universe. It is also a probe into the unknown and it speculates about the types of extraterrestrial life which might reasonably exist."



The new National Air and Space Museum, Smithsonian Institution, Washington, D.C., on The Mall, Independence Avenue, S.W., between 4th and 7th Streets, to be opened 4 July 1976.

"Life In the Universe"

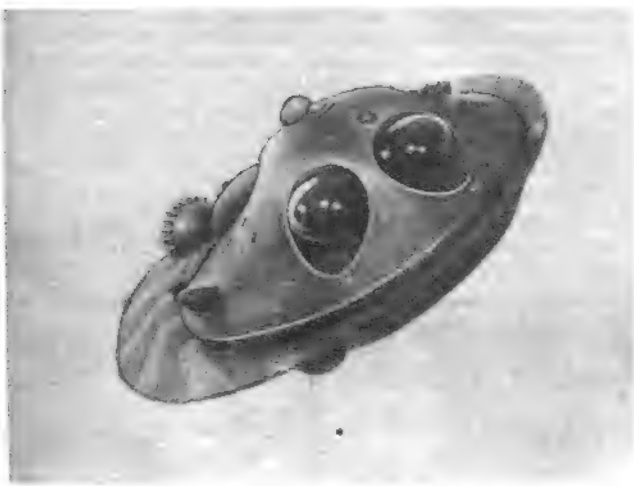
"Life In The Universe" is divided into four parts: the Universe, Life on Earth, the Solar System, and Communications with Extraterrestrial Civilizations. The first three sections are really an introduction to the last since a proper understanding of what exists is necessary to a proper understanding of what may exist.

At the entrance to "Life" the visitor is given this introduction written on the wall: "For centuries men have asked the questions: 'Are we alone? Alone in the vastness of the Universe? Is our star the only star of quadrillions of stars shining upon an intelligent race of beings?' No one knows the answer to these questions. However, we know enough about the Universe to speculate about what we might find out there. This exhibit is a mixture of fact and speculation."

From there the visitor steps into darkness.

Immediately inside the entrance, three small movie screens constantly display animated movies showing the three theories on the creation of the Universe. Next the visitor is confronted with a humbling experience, Charles Eames' film "Power of Ten."

The film opens with a man sleeping on a golf course. The scene is one metre by one metre and viewed from a height of one metre. The scale is 10^0 m. The camera then pulls away and every few seconds another power of ten is added to the scale. The Earth as whole is seen, then the Solar System, the Galaxy, and on until the screen encompasses the known Universe, 10^{24} m wide. Rapidly the camera returns to the man and reverses the scale, zooming in on his hand, through its cells, chromosomes and finally, at 10^{-14} m, a carbon atom nucleus.



Unmanned Extra-terrestrial Spacecraft (carries "Message Block" illustrated on page 232).

Having seen the film, one knows the vastness of the search for other intelligent beings. Three additional slide shows in this section explain the formation of the Solar System and the life of a star. The former is based on computer generated images showing condensation of the planets. The latter shows, on one screen, a star from cold, condensing gas to white dwarf. A large Hertzsprung-Russell diagram to it paces the star's life.

Life on Earth introduces the characteristics of life as we know it. Equipment used by Stanley Miller and Dr. Cyril Ponnamperuma to generate amino acids from models of the primordial atmosphere are on display here. A slide show asking "Is this alive?" presents a number of ordinary objects, including a statue and a Teddy Bear. "The Parade of Life" slides show creatures who once walked the Earth but are now gone. Models of the carbon atom are used to demonstrate why it is the most likely, though not the only, basis for chemical life.

The most entertaining part of the exhibit is TV chef Julia Child, on colour videotape, who announces "We're doing a recipe for the chemical building blocks of life." She then proceeds to mix, in her kitchen, raw chemicals into a primordial soup and explain the workings of Ponnamperuma's apparatus. With the stuff of life mixed, Julia bids the viewer *"Bon appetit!"*

An idea of the variety available in our own backyard is given by the section on the Solar System. The centre of attraction here is a full scale model of the Viking lander that will land on Mars in July, 1976 and a 6 ft. diameter Mars globe. Built up from Mariner 9 photos, the globe is one of three in the world. Elsewhere, paintings by Ludek Pesek show what conditions are like on other planets, and recent newspaper clippings keep the exhibit current.

Communications, the last section of the exhibit, deals with both how to contact alien beings, and how they may look. Two means of getting humans to other stars are offered,

one plausible, the other fanciful. The first is a diagram of a hibernation-type starship in which the human crew would be almost frozen for the duration of the journey. An explanation of the Lorentz transformations and relativity is also given. Just 15 feet away from this explanation of why hyper-light travel is improbable is a model of the starship 'Enterprise' which, for 2½ years, had weekly encounters with a variety of alien beings until sponsors and network officials decided to kill the series. A large set of blueprints are on the wall next to the model. This model has been one of the main attractions of the exhibit, drawing those faithful to the series even though it died in 1970. It is also an indirect tribute to science fiction writers who accepted extra-terrestrial life as a fact long before scientists accepted it as a possibility. Next to 'Enterprise' hangs a 1/10th scale model of the Large Space Telescope.

Drake-Oliver Messages

Two Drake-Oliver messages are available for decoding. Two separate binary messages, one consisting of 209 bits, the other of 1271 bits, are displayed. By pushing one button, the visitor can see the result of improperly arranging the bits in a rectangle – gibberish – or the result of proper arrangement – a diagram showing the sender and his home world (the message sizes are derived by multiplying two prime numbers, 19 x 11 and 41 x 31, to assure proper decoding). Such a message was recently broadcast by the giant antenna at Arecibo, Puerto Rico.

Pick-A-Planet and Pick-A-Star allow the visitor to combine parameters and see what kind of life or environment may result. Pick-A-Planet offers a choice of O-, G-, K-type stars with various ages. Pick-A-Planet offers choices of habitat (land, sea, air), mass (1/3, 1, or 5 Earth mass), and distance (45, 93, or 450 million miles) for a Sol-type star.

The inhabitants depicted in Pick-A-Planet are nicknamed "Bonnie's Beasts" in honour of their creator, biologist Bonnie Dalzell. Some look like Earth creatures because they incorporate features common to survival. Others are totally alien.

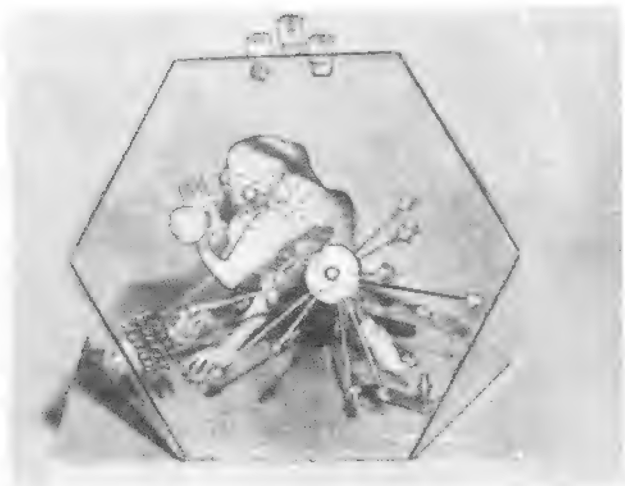
For a dry, Earth-like world, she designed the hexalope, a six-legged antelope. For a low-gravity, temperate world there is a green antelope that more resembles a kangaroo. A high-gravity world is given the 'bandersnatch', a monstrous herbivore with eight legs, a large mouth in its chest, two eyes on a stalk, and ears along the side of its body. The 'Bandersnatch' weighs in at 30,000 lb. on its three-gravity home-world.

The most unusual member of the menagerie is a herbivorous airship that could inhabit a Jovian world, a beast floating along with the greatest of ease thanks to a hydrogen-filled balloon atop its head. There are a total of 27 of Bonnie's Beasts, including one whose principal characteristic, according to its creator, is, that it is disgusting.

Extraterrestrial Message

Certainly the best part of the exhibit, and the one requiring the greatest imagination to develop, is a hypothetical probe from another race. A replica of man's own message to the stars, the Pioneer 10 plaque, is on the wall above the considerably more complex alien probe.

The message is contained in a truncated tetrahedron about eight inches across. Within is a model of a heavy-framed, six-legged creature holding a scale model of the tetrahedron – this gives the scale of the message. Arrayed around it are



Extra-terrestrial Message Block.

Contents of Message:

Corner 1: **Sample of sender tissue, freeze-dried (red-brown granules), with sender emblem.**
Sample of carbon (black powder), with atomic diagram.
Sample of hydrogen-lithium compound (white crystals), with atomic diagrams.

Corner 2: **Sample of iron 60 (silver foil), with atomic diagram, and diagrams of decay products cobalt 60 and nickel 60.**

Corner 3: **Data file: an encyclopaedia of sender culture and technology with translating instructions based on other contents of block and on included diagrams, microcoded into the crystal structure of metal disks, with a painted code progression of gradually diminishing size to indicate the presence of invisibly small data.**

Corner 4: **Radio message: a copy of the radio signal the senders periodically beam at near stars. The signal consists of a hexagonal number of binary digits which, when placed in a spiral array, form pictures.**

Base: **Star map: a white sphere whose centre is the common centre of gravity of a two-sun system whose orbits are engraved around the sphere's base. Metal rods show directions and distances to nearby suns. Beyond the end of each rod is a metal shape derived from the radiation profile of its sun, and beyond that a cylinder whose volume is a function of radiation flux. Similar shapes mark the suns of the central system. A split shape shows that one of the nearby suns is also a double system. Tags on the central sun shapes show their planetary systems. An ornate hexagonal figure opposite the sphere's base symbolizes the galaxy to indicate the star map's relationship to the Galaxy's plane and centre.**

Sender Figure: **A scale model of a member of the sender species of average characteristics, in a posture of ceremonial gift-exchanging. The "gift" is a model of the message block to the time scale.**

National Air and Space Museum/Simpson: Research & Design.

objects which appear meaningless at first. But by pressing a button beneath the model, an explanatory panel is illuminated.

A model of a star with two planets shows how the home of the alien. Pointers radiating from the sun refer to pulsars visible from the home planet (like the Pioneer 10 plaque). Length of the pointers shows relative distance while cylinders

[Continued on page 240

GEORGE C. MARSHALL SPACE FLIGHT CENTER

By Mike Howard

Introduction

On an 1800-acre site in the midst of the U.S. Army's Redstone Arsenal at Huntsville, Alabama, is the Marshall Space Flight Center. The Tennessee River which runs along the southern edge of the Arsenal is one of the Center's most important assets allowing, as it does, the transportation by barge of large rocket stages to and from the facility. Under the directorship of Dr. Wernher von Braun the Center was established on 1 July 1960 with the transfer of buildings and personnel from the U.S. Army Ballistic Missile Agency to the National Aeronautics and Space Administration. Named in honour of the famous soldier and statesman, General of the Army George C. Marshall, the Center was officially dedicated on 8 September 1960 by President Eisenhower.

Marshall's History

From its inception through to 1969 Marshall's major mission was the development of several well known launch vehicle families. Marshall Center scientists and engineers have been responsible for the design of the Redstone, Jupiter, Saturn I, Saturn IB (Uprated Saturn I) and Saturn V boosters.

During the Apollo lunar landing programme 10 Saturn V's performed almost flawlessly to allow 12 astronauts to walk on the Moon and return with more than enough lunar rocks and samples to keep scientists occupied for years to come. The final three Apollo crews were given increased mobility on the lunar surface through another MSFC development the Lunar Roving Vehicle, which was able to convey 2 astronauts several miles from their landing site across the rugged surface of the Moon.

Following on from the Apollo series came the Skylab orbital laboratory. Again Marshall developed much of the hardware for this programme including the two-stage Saturn V that placed the laboratory in orbit (last of the giant boosters scheduled for launch) and three Saturn IB's used to launch the Skylab crews. MSFC also provided certain scientific experiments and programme integration for Skylab.

Marshall Today

Apart from the main complex at Huntsville, Marshall also controlled 3 other sites in the Gulf of Mexico area. The 900-acre Michoud Assembly Facility (MAF) in New Orleans was acquired for the manufacture of Saturn rocket stages, but now that this no longer occurs the MAF is being converted for the construction of the Space Shuttle's External Tanks. The Mississippi Test Facility (MTF) at Bay St. Louis provided test and support facilities for acceptance testing of rocket engines and stages. Some of the facility's test stands are currently undergoing modification to enable development testing of the Space Shuttle's main engines to be carried out.

On 14 June 1974 MTF separated from MSFC to become a NASA field installation in its own right and was renamed the National Space Technology Laboratories (NSTL).

The third Marshall off-site facility is the Slidell Computer Complex, Slidell, Louisianna, which provides computer support for MAF, MSFC, and NSTL. Computer services to NSTL are now supplied on a reimbursable basis.

Due to completion of the Apollo and Skylab programmes the number of people employed at MSFC is expected to level off at some 4,200 during 1975, having reached a peak of 7,200 during the Apollo project. In mid-June 1974 the Center underwent a reorganisation designed to reflect the changes in missions and currently assigned programmes.

Marshall played an important role in the Apollo-Soyuz Test Project (ASTP), having responsibility for mission planning, provision of the Apollo spacecraft's Saturn IB launch vehicle, and management of certain experiments. During the flight the U.S. Apollo spacecraft will rendezvous and dock with the Soviet Soyuz. The two craft will remain in the docked configuration for about two days to allow the astronauts and cosmonauts to conduct joint experiments.

Future Projects

Although the cost of placing a scientific payload into Earth orbit has been considerably reduced over the past 17 years it still costs an average $900 per payload pound. The only major U.S. manned space programme currently planned for the 1980's – the Space Shuttle – is expected to slash this cost to around $160 per payload pound. This reusable spaceplane will be able to orbit, repair, service, retrieve, and replace many varying types of payload. MSFC will provide the Orbiter's engines, the expendable external tank which carries supplementary liquid hydrogen and liquid oxygen for those engines, and the solid rocket motors that fire in conjunction with the Orbiter's engines to lift the vehicle from the launch pad.

As their contribution to the Space Shuttle the European Space Agency will fund, design, test and deliver to NASA a manned laboratory module known as Spacelab. This module will be carried to orbit inside the Space Shuttle's payload bay. Marshall will be responsible for integrated science and application mission planning, systems integration, experiment integration, experiment operator training and operations, refurbishment and overhaul of the Spacelab. First orbital flight of the Shuttle is planned for 1979 with the Spacelab being brought into operation in the early 1980's. A future addition – late 1983 – to the Shuttle system will be the Space Tug. Operating from the Shuttle the Tug will have orbital transfer and manoeuvring capabilities to place payloads into higher orbits than the Orbiter can achieve. MSFC has responsibility for Space Tug management and coordination.

One of the scientific payloads for the Space Shuttle will be the Large Space Telescope (LST). This multi-purpose telescope from its orbit above the Earth's will have an optical range estimated at two thousand million light years. MSFC has management responsibility for the LST.

A programme that is closer to fruition is the High Energy Astronomy Observatory (HEAO) which is also managed by the Marshall Center. Originally planned as a 2-spacecraft series and then suspended due to budgetary constraints HEAO has now been redesigned as a 3-spacecraft series for launch by Atlas-Centaur vehicles into a 225 nautical-mile orbit between 1977 and 1979. The satellites will carry scientific instruments capable of high sensitivity and resolution studies of celestial X-ray, gamma ray and cosmic ray sources to learn more about some of the most mysterious objects in the Universe – pulsars, black holes, neutron stars, quasars, and supernovae. A "follow-on" series of HEAO spacecraft will be orbited in the payload bay of the Space Shuttle.

Acknowledgement

The writer wishes to thank the staff of the Marshall Space Flight Center's Office of Public Affairs for their assistance in the preparation of this article.

F-1: THE CLUSTERED GIANT

A retrospective look at major space achievements by David Baker

In April 1965 NASA took a major step forward in launcn vehicle weight lifting capability by successfully firing, for the first time, a cluster of five F-1 rocket engines, each one more powerful than any liquid propellent motor ever ordered into production.

The F-1 project began in the late 1950's with work at Rocketdyne centred on the development of a 1 million lb. thrust rocket motor. An Air Force contract had been awarded to the company in the summer of 1958 for design, fabrication and initial testing of thrust chamber and injector configurations. In January 1959 NASA contracted Rocketdyne for full F-1 design and development, upgrading the performance to 1.5 million lb. thrust. The idea was already in being; by clustering five of these massive engines into a single booster the space agency would have a useful tool for sending 100-ton payloads to orbit and 50-ton payloads to the Moon.

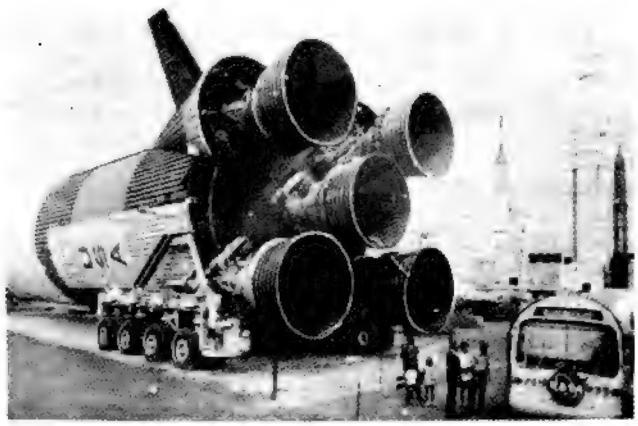
In February 1959 work began on the test stands at Edwards, California, and in March the first injector firings were made. In December 1960 Rocketdyne conducted the first thrust chamber tests and by April 1961 a record thrust of 1.64 million lb. had been achieved. Finally, on May 26 1962, a complete F-1 was fired for a full 2.5 min. at 1.5 million lb. thrust. Only four months earlier NASA had decided to approve development of the Saturn C-5 with a first stage utilising five clustered F-1s. One year later this designation was changed to Saturn V. In July 1962 NASA announced award of a production contract for 55 engines and this was supplemented by additional contracts in 1964 and 1966.

Toward the close of 1962 instability problems delayed development and Congressional concern was expressed over the ultimate availability of this engine. However, by July 1963 the problems had been solved and coupled resonance from the engine pump and fuel flow was circumvented by mechanical isolators. The first production engine was delivered to NASA on 30 October 1963, and flight rating tests were completed by December 1964, some 6 months later than planned.

Probably the most significant aspect of F-1 definition was the decision to aim for such a high thrust level. Yet in several respects the technology applied to F-1 systems design was within the state-of-the-art, albeit on a level never attempted before. It was the sheer magnitude of the thrust rating that opened up the possibility of ambitious space projects for the 1970's.

As designed, the F-1 consisted of a regeneratively cooled thrust chamber with injector, direct-drive turbopump, a gas-generator and a single start control system. The RP-1 and liquid oxygen propellent flow was accelerated by a turbopump driven from a gas generator burning 3% of the total propellent load. Burnt gases were released through a turbine exhaust mounted around the nozzle extension. About 24,800 gallons/min. of LOX flowed through the oxidiser pump, with 15,500 gallons of RP-1/min. delivered by the fuel pump. Therefore, nearly 670 gallons of propellent was delivered to each F-1 per second for 2.5 min. during the launch phase. When clustered in the S-1C stage of Saturn V about 3,360 gallons/sec. were consumed by the five engines!

Other statistics were equally as staggering. The turbine alone developed 55,000 b.h.p. with a speed of 5,550 rpm during mainstage operation. When clustered the five engines produced a total thrust of more than 7.5 million lb. or 160 million horsepower.



Visitors to the Alabama Space and Rocket Center in Huntsville dwarfed by the five huge engines of the Saturn V first stage.

Successful operation of this gargantuan cluster demanded unique facilities at the Kennedy Space Centre. A massive flame trench 58 ft. wide and 42 ft. deep was constructed. Into this the exhaust products spent their energy in the 6 seconds between ignition and lift-off, channelled by a 1.3 million lb. blast deflector 40 ft. high. Taking the form of an inverted V, the deflector was covered with 4.5 inches of refractory concrete consisting of a volcanic ash aggregate and a calcium aluminate binder. Despite this protection nearly 1-inch was worn away with each launch. About 10 seconds before lift-off a series of nozzles poured water over the flame trench at the rate of 8,000 gallons/min., joined by a 50,000 gallon/min. deluge from 29 nozzles above the pad when the Saturn V was released for flight.

The S-1C stage to which the F-1 engines were attached is, again, a massive structure dwarfing anything that had gone before. With a height of 138 ft. and a diameter of 33 ft., the S-1C weighed more than 300,000 lb. dry and carried 4.4 million lb. of propellent. About 214,200 gallons of RP-1 was housed in the fuel tank with 346,400 gallons of LOX in the oxidiser tank. The thrust structure, to which was attached the five F-1s, weighed 24 tons and with fins attached spanned 63 ft. The fins were called upon to withstand temperatures of 2,000°F during the ascent. When the S-1C and its five F-1s had done their work the stage was shunted away from the second stage by eight retrorockets, each generating 100,000 lb. thrust for 0.5 sec. This is more than twice the thrust of the Mercury-Atlas launch vehicle.

Without the remarkable performance of the Saturn V booster, due almost wholly to Rocketdyne for its F-1 work and Boeing for the S-1C stage, none of the Apollo lunar landing flights could have taken place when they did. Nor, indeed, could NASA have launched a fully fitted space station to orbit in 1973.

Today, ten years on, we remember that historic day when a cluster of five F-1 engines fired for the first time attached to the S-1C-T, a static test model of the Saturn V's first stage. In a brief, 6.5 sec., burn on 16 April the concept was validated and after several repeat runs the first full duration (2.5 min.) firing was achieved on 5 August. Although its like may never be seen again the high performance engines of the next generation will owe much to the bold efforts of the Rocketdyne engineers a decade ago.

BOOK REVIEWS

The Invisible Universe: The Story of Radio Astronomy
By Gerrit L. Verschuur, English Universities Press, 1974, pp. 173, £2.95.

Potential readers of this 20th volume in the Heidelberg Science Library should not be put off by the word 'universities' in the publisher's imprint. This is not a dry theoretical textbook, but a popular guide aimed at the amateur astronomer, the planetarium goer, and anyone else wishing to know more about this rapidly advancing science. The author takes his readers on 'a tour of the Universe as revealed by radio astronomy', from our own Sun and its attendant planets to the furthermost reaches of space, treating the subject from the viewpoint of an astronomer rather than a radio engineer. Though informal in style, the text includes some tabulated reference data and is well illustrated.

A large proportion of the book is devoted to recent developments, such as the discovery of quasars, pulsars, and interstellar molecules. Anyone who has not read radio astronomy literature lately may be surprised to hear how fast the latter branch, in particular, is expanding: by the date of going to press, more than 20 different interstellar molecules had been detected, and the list was growing rapidly.

Discoveries of the past decade, which were totally unforeseen in the early days of radio astronomy, make a fascinating story, and one which the layman may find slightly disturbing. The scramble to discover new quasars, new pulsars, and new interstellar molecules was apparently motivated more by the need to gain personal recognition than by purely scientific aims; but, as the author points out, in the modern world financial constraints inevitably play a large part in determining what scientific research is done, and by whom. Having a pulsar named after oneself or one's institution is a good way of securing a continuing flow of research funds, which might otherwise be diverted to somebody else!

The author's realistic approach to such matters is refreshing, but the perhaps the story that he tells is just a *little* overglamourised in some respects. There is a danger that young students may be attracted to radio astronomy by expectations of leading an exciting and eventful life, with momentous discoveries flowing thick and fast, only to be disillusioned when they find that, in reality, a radio astronomer spends much of his time in tedious observations and calculations. Nevertheless, the book can be recommended without hesitation to anyone who requires an informal yet authoritative treatment of the subject, as up to date as any publication in this field can hope to be.

JOHN R. MILLBURN

The Jupiter Effect
By John Gribbin and Stephen Plagemann, Macmillan, 1974, pp. 134, £3.95.

This book which, according to the authors, expounds "only solid scientific evidence and reasoning" presupposes, that the reader will understand that the positions of the planets affect the number of sunspots on the surface of the Sun, which is thus related to the solar wind and cosmic ray activity in the vicinity of the Earth, and this, in turn, causes changes in the atmosphere of the Earth and, consequently, alters the rate of spin of the Earth by a minute fraction of a second per day. From this we find that the plates covering the surface of the Earth, which have got themselves in something of a twist in California, are just waiting to be triggered off.

What better trigger than changes in the spin rate (and hence forces) of the Earth leading to the prediction that Los Angeles stands a good chance of being destroyed by a resulting earthquake in 1982? This is by no means the first book in which some earthbound effect has been correlated with sunspots or astronomical alignments, but it may well become a "classic" of that type.

One of the two forewords is by Isaac Asimov, who "found it more fascinating than the tale of any millionaire found stabbed in any library". Several of the coincidences in the book are reminiscent of this sort of tale as well. The descriptive passages on plate tectonics, the wobble of the Earth, the solar wind etc. are well presented and make interesting reading, but still hard to accept are the many vague links in the chain of argument. Astronomical alignments and astrology are synonomous in the minds of many people, and give the uncomfortable feeling that more than a small belief in astrology is required if one wants to swallow the ideas put forward. Nevertheless, earthquakes are so destructive that any predictive method should be looked at carefully.

The weakest part of the book lies in the significance given to 1982. This coincides with the grand alignment and is close to a sunspot maximum, but nowhere in the book is there any good reason for believing that the San Andreas fault will feel any extra tugs then than at any other maximum. The authors' claim that Los Angeles stands a good chance of being destroyed then is based on some (neglected) work done in the fifties which suggests that even Pluto is important! They do not take the extra step and use earthquakes that do not fit in with their pattern to predict the positions of further planets to the Solar System. Furthermore, the tidal effects on the Sun of the larger asteroids rival that of Pluto, but these have also been ignored.

The most telling argument for 1982, or thereabouts, lies in the record of previous earthquakes in the San Francisco Bay area. The eight reported before the last, in 1906, occurred within two years of sunspot maxima. As the fault is about to slip anyway, the next sunspot maximum makes a good prediction. Correlations with sunspots, or any other phenomena are, however, difficult to treat objectively. If observations suggest, albeit subconsciously, that such-and-such may correlate with them, there is no easy way to estimate the probability that those observations could have occurred by chance.

Despite reservations about the applicability of the "Jupiter Effect" to earthquake prediction, even to such a specialised fault as the Californian one, the book is worth reading.

DR. A. C. FABIAN

Astronautics and Aeronautics, 1972
National Aeronautics and Space Administration, SP-4017, U.S. Government Printing Office, Washington, D.C., 1974, pp. 580, $4.85.

Another excellent compendium in the Annual Summaries of astronautical and allied events prepared by the NASA Historical Staff. As before, the text is prepared from public documents, well referenced, indexed, and with a number of tables and illustrations.

L. J. CARTER

CLASSROOM SATELLITE

Thousands of radio "hams" throughout the world are tuned into their very own satellite. The AMSAT-OSCAR 7, seventh and most complex in a series of communications satellites built by an international group of amateur radio operators, was launched on 15 November 1974, as a "piggy-back" payload on the ITOS-G mission. Unlike most communications satellites, OSCAR is designed for free access by ground stations using relatively simple, portable equipment. OSCAR terminals can be located in automobiles, small pleasure boats, aircraft, or city apartments, and transported where needed in emergencies.

In addition to providing for amateur communications, OSCAR is being used in schools throughout the United States to acquaint youngsters with space science. This is a cooperative programme between NASA's Education Programs Office and the amateur radio community. With inexpensive ground terminals, students are able to receive satellite signals firsthand in their classrooms. Systems in the satellite make it possible for the students to monitor transmissions originating from stations as far away as 5,000 miles, and to receive the spacecraft's telemetry data. Special curriculum material provided to teachers explains how OSCAR can be used to demonstrate the basic concepts of orbital mechanics, radio-wave propagation and the physics of the space environment.

Teachers are also in touch with licensed radio amateurs who volunteered to set up their personal radio equipment for classroom demonstrations.

SPECULATING ON MAN'S NEIGHBOURS

Continued from page 232]

at the end indicate the radiation flux received. One pointer goes to the centre of the Galaxy. Specimens of freeze-dried tissues from the alien's body will enable study of his structure and, perhaps, reconstruction.

Metal foil with $Iron^{60}$, $Cobalt^{60}$, and $Nickel^{60}$ tell the age of the probe by analysis of radioactive decay products. A microfiche disk contains a basic library of information on the alien world. Last but not least is a duplicate of a binary radio message sent by the aliens regularly on 21 cm wavelength (neutral hydrogen).

Overall this probe, designed by Donald Simpson of Albany, California, is a lot bolder than our own Pioneer 10 plaque which simply shows where we are, roughly, and what we look like.

Melvin B. Zisfein, deputy director of NASM and director for the exhibit, said the exhibit "summarizes what is presently observable and deducible about the Universe, particularly about the chances for earthlings to detect and perhaps communicate with alien life. In this quest we must use our storehouse of diverse knowledge, our most sophisticated tools, and, most importantly, our ever-improving minds. To do less might be to deny the thrust of our creation. The search is on, perhaps it will be the most important search in the history of mankind."

"Life in the Universe" represents two years of work by curator Alexis Doster III and designers John R. Clendening and Terezia M. Takacs. Graphics were drawn by Peter F. Copeland and Peter P. DeAnna. It is presently located in NASM's temporary home in the Arts & Industries Building. It will be moved to the NASM building in July, 1976.

NINETY DAYS ON MARS

Continued from page 211]

elevation) for the antenna. The Viking Command and Control, or controller, will transform this information into commands to motors which will then reposition the anntena relative to Earth. Continuous adjustments will be computed during each transmission. It will take approximately 20 minutes for signals to travel the more than 225 million miles between the Viking spacecraft and its home planet.

EXOBIOLOGY SENSORS

Concluded from page 213]

the science of exobiology the methods devised to study alien life will provide an equally valuable insight into the Universe as the results themselves. We may learn which are the truly fundamental characteristics of life and what place intelligent life holds in the Universe, whether great or small. We may find that the answers are rarely as we would wish but if we failed to pursue the search for the truth we would not deserve the right to call ourselves truly intelligent.

SPACEFLIGHT

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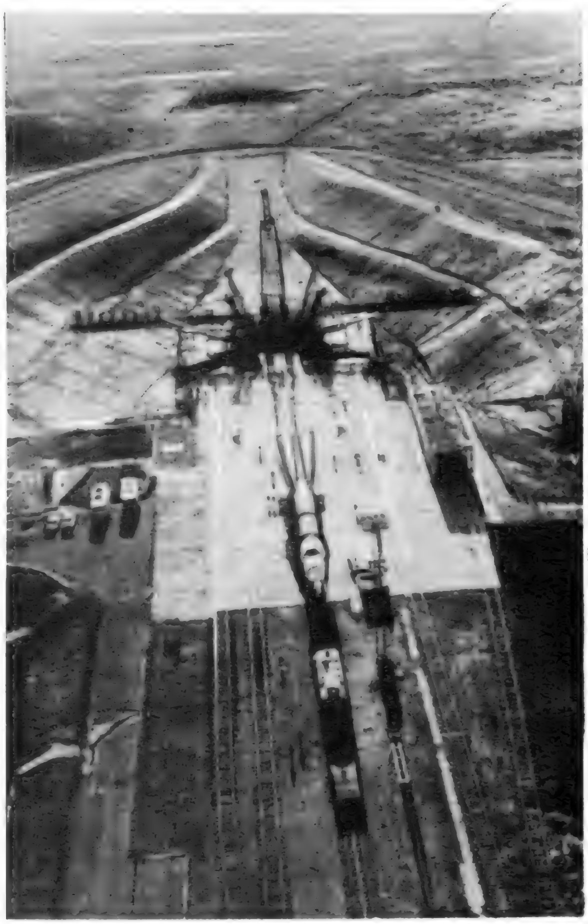

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COVER

SECOND CREW BOARDS SALYUT 4. Following the abortive launch of a manned Soyuz ferry on 5 April, the back-up crew was successful in reaching the orbiting space station on 26 May. *Top left*, Vitaly Sevastyanov (flight engineer) and, *bottom*, Lt.-Col. Pyotr Klimuk (commander). *Right*, Soyuz 18 moves to the launch pad at Tyuratam.

Novosti Press Agency

T 1

SPACEFLIGHT

A Publication of The British Interplanetary Society

VOLUME 17 NO's 8 & 9 AUGUST-SEPTEMBER 1975 *Published 15 July 1975*

Owing to the recent trade agreement giving employees of the printing industry four weeks annual holiday, this is a combined issue covering the months August and September. The October issue of *Spaceflight* will be published during the third week of September, as usual.

MILESTONES

May

5 Mitsubishi Electric announces that the company has received a Yen 78 million ($280,000) contract from Japan's National Space Development Agency for the initial design of an experimental geo-stationary communications satellite. Plans include launching two such satellites in 1978 by Japan's new three-stage N-type launcher which is based on a licence-built Thor first stage. Each 287 lb. (130 kg) satellite will be about 6.5 ft. (2.0 m) long by 4.6 ft. (1.4 m) in diameter.

7 NASA launches third and last Anik 3 domestic communications satellite for Telesat Canada by Delta rocket from Cape Canaveral (which arrives in geo-stationary orbit 104° west longitude 22 May).

8 Small Astronomy Satellite (SAS-3) is launched from San Marco platform offshore of Kenya "to survey galactic X-ray sources." Orbit of 430 lb. (195 kg) satellite is 499-508 km inclined at 3.01° to equator.

17 CNES launches twin satellites Castor and Pollux (D-5B and D-5A respectively) by second Diamant BP.4 from Kourou. Guyane Space Centre, into 277-1,277 km orbit inclined at 29.95° to equator. Pollux has 3.5 Newtons (0.75 lb.) hydrazine micro-thruster to modify path of 80 lb. (36 kg) satellite.

20 High-power ATS-6 geo-stationary communications satellite begins transfer from position just west of Galapogos Islands to reach new location above Lake Victoria in East Africa about 1 July, for use as communications link with spacecraft of Apollo-Soyuz Test Project and subsequent instructional TV experiment in India.

22 NASA launches 3,000 lb. (1,360 kg) Intelsat 4 by Atlas-Centaur from Cape Canaveral for positioning in geo-stationary orbit at 61.5° east longitude. Satellite is last of series. Complete system consists of three satellites above Atlantic and two each above Pacific and Indian Oceans. (Launch of first of six higher capacity Intelsat 4A's scheduled 10 July).

Soviets launch Soyuz 18 with cosmonauts Lt-Col. Pyotr Klimuk and civilian flight-engineer Vitaly Sevastyanov from Tyuratam at 5.58 p.m. (Moscow time) to continue experiments aboard Salyut 4 space station. After two Earth-revolutions, orbit is 193 x 247 km x 51.6° inclination; period 88.6 min.

26 Professor U. R. Rao says scientific experiments aboard India's Aryabhata satellite, launched 19 April in the Soviet Union, had to be shut down after 60 orbits because power supply was failing to supply enough current to run both experiments and satellite's housekeeping systems.

26 Soyuz 18 cosmonauts begin docking operation with Salyut 4 at 9.11 p.m. (Moscow time), at first under automatic control, then manually from a distance of 100 metres (final contact speed 0.3 metres/sec). First time that USSR has succeeded in putting two separate crews aboard same

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MARINER-VENUS-MERCURY 1973 PROJECT HISTORY

By David Baker

PART 3

Continued from May issue, page 194]

Superior Conjunction

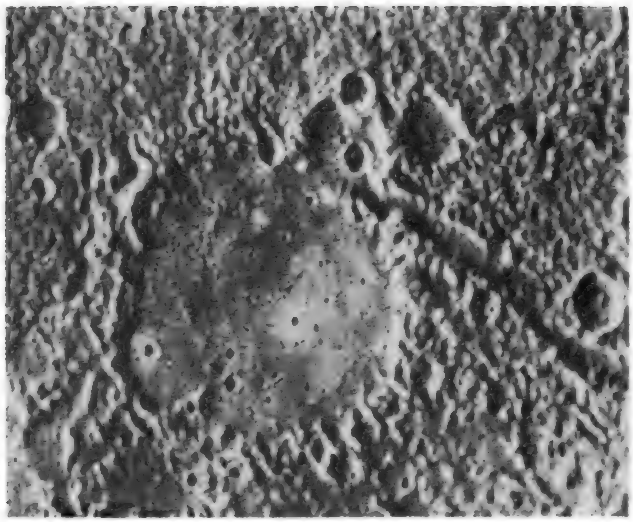
By 6 June 1974, the spacecraft had moved around the Sun to superior conjunction and the dual S-band and X-band radio signals from the high-gain antenna passed within 1.67° of the solar "surface" as viewed from Earth. The effect of the solar corona on the signals was recorded at the Goldstone tracking station with data analysed at the Stanford University Centre for Radio Astronomy and at JPL. The relativistic effects of the Sun's enormous gravitational field was first tested in late March but by the time of superior conjunction on 6 June the radio signals displayed a delay of 160 μ seconds and a maximum change rate of nearly 3 μ seconds/day. Mariner 10 was now 67 million miles from the Sun, 160 million miles from Earth and moving at a solar reference velocity of 71,600 mph.

TCM-5, the sixth burn performed by the on-board rocket motor (TCM-4 was a two part manoeuvre), came at 20:09 GMT on 2 July 1974. To achieve the desired orientation the spacecraft was rolled at 56.1° and then pitched 57.8° followed by ignition and an 18.8 second burn with a ΔV of 11 ft/sec. About 60 ft/sec. ΔV capability now remained for further refinements required to support a third Mercury encounter. The effect of TCM-5 was to put Mariner on course for a 29,800 mile pass at 20:59 GMT on 21 September 1974. If uncorrected the post-Mercury II trajectory would permit Mariner to achieve Mercury III encounter at 2:13 GMT on 16 March 1975, passing to within 164,000 miles of the planet. Quite simply, by increasing the fly-by altitude at Mercury II the spacecraft received less of a trajectory turn which lowered the fly-by range at the third encounter. This moved the range well within the on-board course correction capability and preserved the options for several alternative fly-by profiles selected by further course changes in the period following Mercury II.

Degradation of Equipment

During the post-Mercury I cruise phase the combined effects of time and the dominating influence of the Sun had taken its toll on Mariner 10. Very shortly after periapsis the solar arrays received an additional 90-watt load resulting in increased temperatures. The cause was still unknown and less than a month later, by late April, the telemetry subsystem experienced a failure resulting in the loss of nearly half the engineering format. Then the low-energy particle detectors in the Plasma Science Experiment reached the end of their usual life and were finally turned off. Most important of all, however, was the loss of the on-board tape recorder during August. All TV images would henceforth be transmitted real-time at high and reduced resolution rates. Because Earth was to be 105 million miles away from the spacecraft during the second encounter with Mercury plans were made to link the 210 ft. DSN dish at Goldstone with the two 84 ft. dishes by microwave so that the signals could be combined before processing thus enhancing each image.

By 13 September 1974, Mariner 10 was receiving its computer updates for the automatic sequence. The cameras were turned on at 15:31 GMT on 16 September and an optical navigation exercise, in which the TV cameras were pointed at such an angle that they included views of Mercury and a reference star, began at 16:51 GMT. Views of the planet proper began at 20:28 GMT on 17 September in reduced resolution mode whereby every fourth picture element was transmitted to Earth. UVS airglow scans began at 21:31 GMT and continued for 20 minutes. Following this, nearly



One of the most remarkable pictures of Mercury obtained by Mariner 10 shows a large valley 4.5 miles (7.2 km) wide and more than 62 miles (100 km) long alongside a large flat-floored crater about 50 miles (80 km) across.

National Aeronautics and Space Administration

300 images were transmitted in support of the optical navigation exercise mentioned above and a photometric calibration using various filters and exposures was conducted between 19:01 and 23:11 GMT on 18 September.

Mariner 10 was approaching Mercury on the sunlit side of the planet with the sub-spacecraft point at 40°S at periapsis. During the previous encounter the TV cameras had viewed one half of the visible disc on the approach and the other half as it receded from the planet. Mercury II allowed a full frontal scan of the sunlit side plus slant-angle examination of the south pole. Images transmitted from the two encounters showed 60% of the total surface area. Because the rotation period of Mercury is 58.6 days, and its orbital period is 88 days, one sunset to sunset "day" requires two revolutions of the planet about the Sun. In other words, one Herminian day equals two Herminian years. As Mariner 10 was returning for a close pass 176 Earth days after the first encounter the single rotation of Mercury with respect to the Sun brought the same topographic features on to the sunlit side.

UVS airglow scans were made for 10 minutes starting at 23:11 GMT on 18 September and at 20:57 the next day Mariner shot 64 images of Jupiter for TV calibration. The Incoming Far Encounter Sequence (IFES) TV began at 20:32 GMT on 20 September and lasted 59 minutes during which 84 frames were transmitted to Earth. Incoming Near Encounter Sequence (INES) views were taken during a 16 minute period beginning 17:47 GMT on 21 September. The 18-frame mosaic had a resolution of 1.7 miles. Prime encounter TV began at 19:01 GMT and covered the closest approach of 29,800 miles at 20:50 GMT. By the end of this phase, at 23:00 GMT, more than 300 views had been sent to Earth with resolution at periapsis down to 0.6 mile. The Outgoing Near Encounter Sequence (ONES) views were taken from 00:21 GMT on 22 September. Far Encounter TV began at 20:32 GMT and ended at 21:31 GMT the same

day. Partial resolution TV was transmitted for 2 hours beginning 01:01 GMT on 23 September. The TV cameras were finally turned off at 03:01 GMT, six days 10 hr. 10 min. after operations for Mercury II began. UVS airglow scans were performed between TV transmissions.

By now only 0.9 lb of nitrogen gas remained in the attitude control system and as Mariner resumed its path around the Sun useage rates had been lowered to just 0.003 lb/day. If the spacecraft was to have 0.2-0.3 lb. of propellent left for attitude control during the Mercury III encounter useage rates would have to be reduced to approximately 0.0025 lb/day. Currently, Mariner 10 would pass within 164,000 miles of Mercury at 02:13 GMT on 16 March, 1975. Additional TCM operations would target the spacecraft for a night-side pass, satisfying the requirements of the scientific community by conducting further measurements of the magnetic field.

Suddenly, on 6 October, the spacecraft sensed a structural oscillation building up and commanded the attitude control thrusters to fire, thereby stabilising the vehicle and preventing loss of Canopus lock. The long booms, the two solar panels and the high-gain antenna were inciting a pendulum action and before the rates could be damped out Mariner 10 had expended 0.2 lb. of propellent, leaving 0.6 lb. for the long cruise to Mercury III. Immediately, Spacecraft Team Chief William I. Purdy realised the impact of this anomaly on the attitude control propellent supply and headed a crash effort to develop a new flight control method. Working with Purdy were Jerry Hardman of Boeing and Larry Schumacher from JPL. Before long these two engineers had come up with a passive roll axis control method whereby the pressure from solar radiation impinging on different spacecraft appendages would stabilise the vehicle and reduce propellent consumption. The angular orientation of the high-gain antenna and twin solar cell panels allowed controllers on the ground to literally set the sails and steer Mariner in true nautical fashion. All the way to Mercury III encounter the spacecraft would use this "solar-sailing" technique and conserve valuable propellent.

With trajectory parameters from the post-Mercury II encounter to hand a course correction manoeuvre was prepared so that Mariner 10 could fly close past the planet on the dark side on 16 March 1975. From a projected periapsis point of 165,000 miles the spacecraft would move closer in as a result of a trim burn and optimise the approach profile around the preferred scientific objectives. TCM-6 was performed at 21:52 GMT on 30 October 1974. The 83 second engine burn imparted a 47.6 ft/sec. velocity change which moved the periapsis point for Mercury III encounter to within 3,225 miles of the planet's surface. Mariner 10 would be commanded much closer to the planet but the magnitude of the burn required to shift the trajectory in from 165,000 miles would provide very little margin for error and a slight overburn could display an impact course and because of this the trajectory shift was divided into two components separated by some 3½ months. TCM-6 had moved the trajectory as close as possible to the planet without causing the planet-side of the dispersion ellipse to sweep the surface.

The seventh TCM operation was conducted on 13 February 1975, at 21:55:49 GMT when the spacecraft was 27.97 million miles from Mercury and 57.9 million miles from Earth. In a 12.5 second, 6.6 ft/sec., burn of the main propulsion unit the periapsis point was shifted to a planned miss distance of 190 miles but at least two weeks of tracking would be needed to define the degree of accuracy achieved during the manoeuvre. Nevertheless, only 0.3 lb. of attitude control propellent remained and this would be substantially depleted during the upcoming encounter operations. Quite obviously a Mercury IV encounter was out of the question, with insufficient propellent available for maintaining cruise attitude during the six months to September 1975 when Mariner 10 would approach to within 3 million miles of the planet.

Danger of Mercury Impact

As calculations were performed on the final trajectory plots it became obvious that the spacecraft would fly perilously close to the surface. On its present course Mariner 10 seemed aligned for a 31 mile pass, ± 56 miles! As a result a TCM-8 burn was made late on 6 March to move this out to 125 miles and prevent surface impact. The 3 second, 1.5ft/sec., burn was initiated at 18:55 GMT when the spacecraft was 5.3 million miles from Mercury. The planned 125 mile fly-by point carried an uncertainty in one-sigma range variance of 60 miles which produced a 2% probability of surface impact, an acceptable condition due to the high priority given to a close pass.

Up to now Mariner 10 had been cruising in a random roll mode whereby the spacecraft spun very slowly thereby providing an attitude stability coupled with the solar-sailing technique outlined above. It was now necessary to stop the roll and lock up with the celestial reference star Canopus so that the high-gain antenna could be pointed at Earth and the science platform pointed at Mercury. On 10, 11 and 12 March JPL engineers studied the low-gain antenna patterns and defined a preliminary schedule for conducting a "zero-gas" Canopus reacquisition sequence. This would demand sending a command to enable the roll axis attitude control when the star entered the tracker's field of view. Ground communications could be received back at Mariner 10 within 18 minutes (9 min. each way), with Canopus still in the tracker, thus executing an attitude-hold command and preventing the spacecraft rolling out of alignment. The whole zero-gas plan was conceived in efforts to inhibit the liklihood of a structural oscillation caused by the conventional roll-search method. This had been the problem on 6 October 1974, when propellent was expelled in correcting the oscillation.

The preferred time for nulling the roll rate by this technique was found to lie between 15:30 and 18:30 GMT on 12 March. Unfortunately, this period corresponded to the gap in communications between tracking stations at Goldstone and Canberra and the project team were compelled to ask the Deep Space Network to release these stations on the 13th. This time had been allocated to the Helios project during its optical close approach to the Sun, scheduled for 11:12:15 GMT on 15 March, but the big 210-ft. dish antennae were transferred to the Mariner science team to secure the attitude of the spacecraft. Due to a high roll rate the first attempt was unsuccessful; Mariner 10 rolled by 7° after acquisition of Canopus and was then commanded back 140° to calibrate the high-gain antenna position and thereby derive the precise attitude coordinates. The spacecraft was halted 40° up-roll of Canopus to confirm the exact position and then allowed to drift up to 7° off Canopus. Tracking the high-gain antenna during final roll-in allowed commands to get through to secure the spacecraft in all-axis inertial mode before the star drifted out the field of view. All three axes were then aligned with the celestial reference and the

encounter sequence began with commands to activate the TV camera beams at 10:08 GMT, 15 March.

Third Fly-by Objectives

The fly-by profile had been selected for its scientific value and of those objectives none were more puzzling than the indicated characteristics of the magnetic environment. Earth and Jupiter are the only planets known to have a magnetosphere but the first encounter with Mercury in March 1974 gave the inner-most world a new and profoundly significant appearance. Mathematical analysis showed Mercury to have a 350 gamma field at the equator and a 700 gamma field at the poles, with the axis of magnetic dipole tilted 7° at the spin axis. The issue in debate concerned the origin of the field; did it derive from complex induction with the solar wind or has it evolved by virtue of some geophysical process during the assymetric construction of the planet? The second encounter with Mercury, in September 1974, was unable to address these questions due to the sun-side fly-by trajectory. Passing some 29,800 miles from the planet Mariner 10 was well outside the magnetospheric boundary. Mercury III was optimised around these requirements and assigned a night-side pass so the magnetometer, the plasma science instrument and the charged particle experiment could get a good solid look at the magnetosphere and more precisely define the strength of the field closer to the surface. Altitude at the first encounter had been more than 400 miles and the 125 mile anticipated fly-by at third encounter was expected to yield much valuable data.

Encounter science operations began with TV calibration on Mercury at 09:12 GMT, 16 March, with 11 mile resolution views transmitted at 22 kbps. This operation endured for about one hour and was followed, beginning at 20:01 GMT on 16 March with a 33 minute ultraviolet spectrometer scan of the planet. It had been hoped to obtain the first colour mosaic in a 62-minute sequence beginning at 15:51 GMT but transmitter problems at the Goldstone tracking station prevented this. The plan had envisaged taking two 16-frame mosaics and transmitting the images at 22 kbps.

Final trajectory plots were completed just prior to the UVS sequence and Dr. Jeremy B. Jones, the Navigation Team Chief, sent ripples of alarm through the science teams when he revealed the solutions to indicate an impact with Mercury. However, the Incoming Encounter Sequence was initiated at 20:34 GMT and TV imaging was sent down to the Canberra tracking station. The original plan envisaged reception of images at a 117 kbps rate with the 210-ft. diameter antenna at Goldstone and Canberra but the Goldstone transmitter failure took that station off line. In addition, a cryogenic cooling problem with the 210-ft. dish's maser cone at Canberra prevented high-bit-rate data transmission and the TV was sent down at a slower rate of 22 kbps to the 85-ft. antenna at Canberra. Because of this only one-quarter frame photographs were possible. Ultraviolet spectrometer scans were performed from 21:36 to 21:41 GMT and again from 21:51 to 21:58 GMT, just 41 minutes prior to encounter.

At 22:31 GMT Mariner 10 crossed the magnetospheric bow shock wave, about eight minutes after the Incoming Encounter Sequence images stopped. The ultraviolet spectrometer began a 21-minute scan at 22:23. The magnetopause was crossed at 22:39 with the point of closest approach coming at precisely 22:39:24 GMT. Mariner 10 sped past the planet at an actual altitude of 204 miles centred 70° north of the equator. The maximum magnetic field strength (400 gamma) was recorded at 22:49 and the magnetopause was traversed on the outgoing leg at 22:56 GMT.

The Outgoing Encounter Sequence had begun at 22:44 GMT with TV transmitted at 22 kbps instead of the planned rate of 117 kbps due to reasons outlined above. Finally, the bow shock wave was left behind at 22:59 GMT. An eight minute ultraviolet spectrometer scan was performed beginning at 23:01 followed by a five minute scan at 23:36 GMT. The OES phase ended at 00:48 GMT, 17 March, and two 32-frame colour mosaics scheduled for 03:41 and 09:11 GMT were cancelled because of the Goldstone trouble. It had been impossible to use the Infrared Radiometer due to the axis of alignment and the angle of the spacecraft during the polar pass. Good celestial mechanics data was obtained, however, and the lack of occultation provided a continuous stream of information on the precise nature of the trajectory which permits enhanced derivation of planetary mass and the orbital characteristics.

The final TV pictures were taken at 22:00 GMT on 17 March and additional ultraviolet spectrometer scans were performed immediately thereafter and throughout 18, 19 and 20 March. It had been hoped to keep Mariner 10 active through to 1 April but the deteriorating propellent situation demanded premature shut down. Engineering test of the failing spacecraft got under way during the early hours of 21 March with attempts to open the stuck aperture door on the Scanning Electrostatic Analyser, to no avail. Next, at 17:00 GMT, the solar panels were turned to their full 78° position to observe the induced mass effects, followed by a full 180° slew with the scan platform carrying scientific instruments. Then, at 22:00 GMT the Data Storage Subsystem was tested in an attempt to reactivate the tape recorder which had failed about one month before the second encounter with Mercury. The radio transmitter was put through a test sequence beginning at 02:45 GMT, 22 March, when the travelling wave tube amplifier was turned off and then on again at 17:45 GMT.

After the central computer and sequencer had been reloaded at 03:00 GMT on 23 March the spacecraft was put into a all-axis drift mode to determine centre of pressure from solar wind impingement. More radio checks followed and then, at 10:50 GMT on 24 March, JPL put Mariner in an all-axis drift mode a second time to attempt solar-sailing. The gyroscopes were turned on in an attempt to reacquire Canopus but indications, at 11:16 GMT, were that the attitude control propellent was finally exhausted and at 11:54 the spacecraft lost lock on the Sun and Canopus. A DC55 command was sent out from Goldstone at precisely 12:00 noon GMT on 24 March to switch off the travelling wave tube amplifiers for the last time. The command was executed on board Mariner 10 at 12:10 GMT at which time the spacecraft had pitched 21° off the Sun line causing temperatures to rise due to the lack of shading on the electronics. At 12:21 GMT the Goldstone station received the last word from Mariner that it was signing off. The operational phase was over.

Conclusions

In several respects the Mariner-Venus-Mercury 1973 project demonstrated significant advance on earlier programmes. These included the first gravity-assist fly-by of a second planet from the deflected trajectory induced by a primary target, the first TV views of Venus, the first investigation of Mercury,

the first planetary re-visit on a fly-by profile, the lowest cost/return mission in space science history and the most effective manipulation of real-time planning (by using a wholly new technique, solar-sailing, to effect attitude stabilisation) ever achieved. To accomplish these six major milestones the National Aeronautics and Space Administration is to be congratulated on overall support of the venture, the Deep Space Network is to be lauded on the meticulous precision with which it supported tracking requirements and the Boeing Company is praised for the sustained perfection of contracted hardware. Through 13 Saturn V launches, three Lunar Roving Vehicle missions and now the highly successful Mariner 10 flight Boeing have consistently maintained their 100% reliability record, an enviable qualification of commendable management and production techniques.

Beyond these meritorious achievements must come the accolades won by the Jet Propulsion Laboratory by their continued demonstration that a reliable team of experienced technicians, engineers and scientists is an equal match for the demanding mission plans of planetary research. New ground was won in successfully demonstrating the feasibility of a multi-planet mission and JPL is to be congratulated on the precision with which the operation was carried out. This will doubtless give confidence for the exacting multi-planet fly-by missions incorporated in the 1977 Mariner-Jupiter-Saturn project.

The television views of Venus will certainly add useful information to the meteorology of the inner planets and provide an operating base for the 1978 Pioneer-Venus flights. The first-ever investigation of Mercury must rank alongside the truly outstanding revolution in planetary science dictated by Mariner 2 (first to Venus), Mariner 4 (first to Mars) and Pioneer 10 (first to Jupiter). Already, the influence on planetary geophysics is quite profound, especially with the discovery of a magnetic environment for this slowly revolving body. The three encounters with Mercury will probably constitute a record for the remainder of the century and they provided a remarkable opportunity for sustained real-time planning on a new scale of perfection.

At the onset of mission planning the project team were restrained by a \$98 million ceiling and the initial mission (encounter at Venus and first encounter at Mercury) was performed for just \$96.87 million. The second and third encounters at Mercury cost an extra \$2.98 million displaying a project run-out cost of \$99.85 million, an overrun of slightly less than 2% for four planetary encounters versus the planned two. Mariner 10 probably represents the last of the first generation, solar-panel type, vehicles to leave the stable. All planetary missions envisaged for the next six years will use nuclear generators (except for Pioneer-Venus) and apart from the generic application of the Viking Orbiter (due to remain on station in Mars orbit while landers descend to the surface in 1976) there are no planned developments in the future. Meanwhile, NASA, JPL and Boeing can feel assured that they have forged a significant landmark in the never ending quest for the history of the Solar System. MVM-73 will join ranks with other truly commendable activities of mankind and take its place in history as a signpost on the road of knowledge.

T 6

ARYABHATA IN ORBIT

By H. P. Mama

Introduction

India's first Earth satellite, named Aryabhata after the great fifth century astronomer and mathematician, was placed into orbit on 19 April by a Soviet two-stage Intercosmos rocket from the cosmodrome at Kapustin Yar near Volgograd. The orbit achieved – very close to design values – ranged between 564 and 623 km inclined at 50.4 deg. to the equator; period 96.41 min.

The launch was witnessed by Dr. Satish Dhawan, Chairman of the Space Commission; Dr. U. R. Rao, Director, Indian Scientific Satellite Project, and about 40 other Indian space scientists and engineers. India became the eleventh country to orbit an Earth satellite. At 360 kg, the spin-stabilised Aryabhata is also the heaviest maiden satellite launched by any country to date. Among other significant features of this venture are that all the on-board systems and the payloads continue to work perfectly and that all three payloads as well as much of the on-board and ground-based equipment, was produced in India.

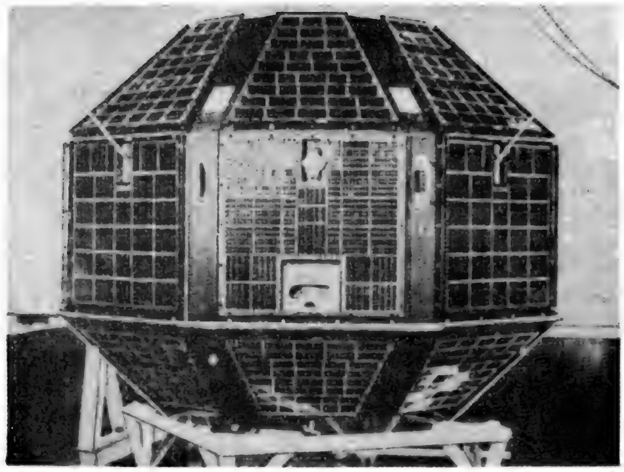
Project Responsibility

The main work on Indian Scientific Satellite Project (ISSP) was in the hands of about 200 technical staff and 50 administrative personnel under Professor U. R. Rao, who had formerly worked under the late Dr. Vikram A. Sarabhai – the Father of India's Space Research – at the Physical Research Laboratory. While the overall responsibility for the satellite was vested in the ISSP at Peenya Industrial Estate, near Bangalore, a number of companies have been involved in its manufacture. These include Hindustan Aeronautics Ltd., Bangalore Division (HAL), the Controllerate of Inspection Electronics (CIL), the Bhabha Atomic Research Centre (BARC), Bharat Electronics Ltd. (BEL), Central Machine Tool Institute (CMTI), Electronics Corporation of India Ltd. (ECIL), Hegde and Golay Ltd. (a company specialising in quartz crystal watches), Indian Telephone Industries (ITI) and the National Aeronautical Laboratory (NAL).

Fabrication of the satellite's outer shell was undertaken by HAL, while CIL and NAL undertook the dynamic and static testing. Screening and testing of the electronic components was entrusted to CIL and BEL. BARC and ECIL assisted ISSP in fabricating the country's first simulation chamber, while the dynamic balancing machine was the work of NAL.

While Indian scientists have usually been severely hampered by the lack of equipment, facilities and resources, there has always been a wealth of latent scientific talent. Many of the scientists at institutions like the Tata Institute of Fundamental Research (TIFR), Bombay; the Physical Research Laboratory (PRL) and Space Applications Centre (SAC), Ahmedabad; and the Space Science and Technology Centre (SSTC) of the Vikram Sarabhai Space Centre (VSSC) at Trivandrum, are visiting research scholars at leading institutions abroad. Some of them actively participate in major NASA projects.

Thus, when the Soviet Union offered India facilities for the launching of a satellite, that country did not have to start entirely from scratch. Following the signing of the agreement between the Indian Space Research Organisation and the Academy of Sciences of the USSR, on 10 May 1972, the *Indian Scientific Satellite Project (ISSP)* was set up in October of that year, with facilities in two buildings at Peenya. That city offers good aerospace and electronics support facilities. ISSP currently has a well-equipped electronics laboratory of 10,000 ft.^{2} floor area, clean room for the integration and testing of the satellite, a thermal laboratory, magnetic test facilities, structural, control and stabilisation laboratories, a thermovac chamber, drafting facilities, a small workshop, etc.



Flight model of Aryabhata, India's first satellite.

The Satellite

The polyhedral satellite has 26 flat faces, a maximum diameter of 1.47 m and a height of 1.11 m. Its geometric design is dictated by the shape and volume of the satellite fairing of the launch vehicle and by the requirement for dynamic stability about the spin axis. The three on-board payloads are for experiments in X-ray astronomy, aeronomy and solar physics.

The 22 kg X-ray astronomy payload, designed by PRL's Professor U. R. Rao and Dr. K. Kasthurirangan, was designed to detect X-ray emissions in the 2-15 KeV range. X-ray studies include flux and energy spectrum of X-rays from discrete sources as well as the diffuse background time variations in the intensity of the former, anisotropy in the diffuse background, and hopefully, the identification of new sources.

The solar physics payload produced by a TIFR team headed by Professor R. R. Daniel and including Dr. Lavakare and Dr. Damle, is designed to detect the possible emission of neutrons in the range 10-600 MeV and gamma rays in the energy band of about 0.2 to 20 MeV during periods of violent solar flares. The equipment consists of a large-area CsI (TI) scintillation counter capable of measuring fluxes as low as 10^{-3} particles/cm^2/sec. It will also be possible to measure any continuous emission of solar neutrons and gamma rays by comparing measurements made within the Earth's shadow with those outside it. The payload will also study the variation of atmospheric neutrons and gamma ray fluxes with latitude and the occurrence of gamma ray bursts. This experiment is particularly important as no previous work of this nature has been done in this energy range at equatorial latitudes, a location even more suitable for this work than deep space.

The 10 kg aeronomy payload of the PRL team headed by Professor Satya Prakash and including Dr. B. H. Subbaraya, consists of an electron trap to study the energy

spectrum of suprathermal ionospheric electrons of up to 200 eV, and an ultraviolet detector primarily designed to monitor scattered Lyman Alpha radiation in the night sky.

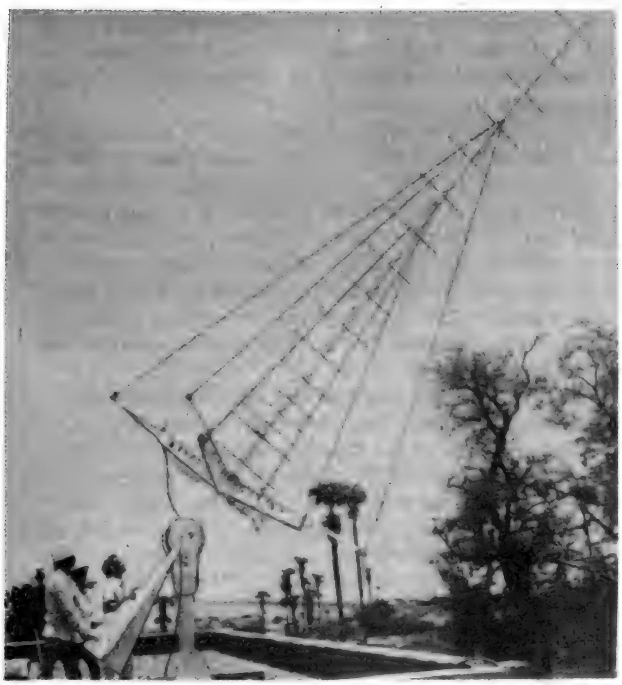
On-board systems include a passive thermal control unit, a PCM telemetry system, a telecommand system, a spin-up system, a power source, tape recorders, and an attitude sensor.

The *passive temperature control system,* utilising paints of the desired conductivity and emissivity, maintains internal temperatures in the range 0°C-40°C during each orbit, while outside temperatures would vary between -100°C and +75°C. The *PCM telemetry system* operates at 2,560 bits per second at 136 MHz. It radiates about 600 milli-watts of power through an omnidirectional antenna. About 46 watts of power is supplied by 1,800 Soviet-made N-on-P *silicon solar cells* covering 36,800 sq. cm of the satellite's outer surface, with standby power available from 20 imported Ni-Cd batteries. Redundant Soviet-supplied *tape recorders* can store 40 min. of data for transmission to Earth on command. This means that only 40 min. of data can be recovered per orbit. The recorder plays back data to Earth stations on command at 10 times the recording rate, i.e. in about 4 min.

The ground segment of the *telecommand unit* basically consists of an encoder and a 1 kw RF transmitter radiating at 148 MHz. The transmitting antenna on the satellite also acts as the telecommand pick-up aerial. Commands for 35 different operations can be transmitted with this equipment. A mercury *nutation damper,* developed by the Control and Stabilisation Group and fabricated from fibreglass by the National Aeronautical Laboratory (NAL) had been installed to reduce the satellite's initial nutation angle of 3° to less than 1° in as little as 4 min.

The Soviet Union had also supplied the *spin-up mechanism.* To provide dynamic stability to the satellite in orbit, it is spun about its axis of greatest moment of inertia. Torque for spin-up is provided by nitrogen gas stored at 200 atmospheres pressure in six spherical titanium bottles and ejected through two nozzles located 180° apart. Gas from the first bottle was ejected by a programmed command immediately after orbit insertion, since the launch vehicle itself was not spinning, followed shortly by the second. The four other bottles were being fired in turn by ground telecommand at the rate of roughly one every 25 days. Thus the spin rate could be continuously maintained within the desired 10-90 rpm margin to keep the coning angle of the spin axis below 1°. This supply of nitrogen gas is a limiting factor in the service life of the satellite. The satellite's *attitude sensor,* consisting of a triaxial fluxgate magnetometer and a digital solar sensor, is accurate to about a degree.

The telecommand antenna at Srihikota.



Pre-flight Testing

Several working models of the satellite had been produced for test purposes, apart from a redundant flight model. This second flight model is to be launched at a later stage with an Earth resources survey payload consisting of television cameras. A sum of Rs. 5 million has already been set aside for this project. Experiments with aircraft-based instruments have already been conducted under project ARISE (Agricultural Resources Inventory and Survey Experiment). For all future satellites, the role of the Russians will be mainly that of consultants. The first mechanical prototype was subjected to physical measurements like centre of gravity, moment of inertia, weight and dynamical balancing, etc. Static and dynamic tests were conducted to qualify it for the space environment.

A half-scale *satellite working model,* fitted with all its subsystems, was carried to 25 km beneath a 3 million ft.^{3} hydrogen balloon from Hyderabad on 5 May 1973 to prove the communications and telecommand link and test the electrical behaviour of the X-ray astronomy payload. Ascent rate of the balloon was controlled through a ballast system of iron filings that were drained out at a controlled rate by actuating a magnetically controlled valve through radio command. The payload was separated from the balloon by a radio command and recovered by parachute, about 4 hr. of uninterrupted reception being obtained prior to payload recovery.

An engineering model of the satellite, with all the subsystems previously tested under the most rigorous environmental conditions, was next flown over Sriharikota beneath an Indian Air Force Alouette III helicopter for an independent performance check of its on-board antenna pattern, communications link, telemetry reception and telecommand sensitivity levels, and to determine the sensitivity of the Indian-designed and fabricated telemetry receiving antenna at the Sriharikota Range (SHAR). At a later stage, a mechanical prototype was sent to Moscow on board an Aeroflot An-12 which had been specially flown to Bangalore for that purpose.

Of the three ground stations available for use with the satellite, only those at Sriharikota near Madras, and Bear Lake near Moscow have command transmitting capability while the French station only offers facilities for tracking the Aryabhata and for *real-time* data collection.

Sriharikota, the main facility, is currently manned by 10 Indian scientists, headed by NASA-trained Project Director Dr. Y. Janardana Rao, and assisted by two Soviet scientists, I. D. Egorov and V. Chenko.

Sriharikota has a steerable antenna array and a complete set-up for receiving data from the satellite, displaying them, and undertaking preliminary analysis of the same. It also has telecommand equipment and a tracking network consisting of a Doppler and a tone range/telemetry interferometer system.

The second ground station at Bear Lake, set up in association with the USSR Academy of Sciences, also has the Indian designed and built telecommand station to command the satellite for both real time and stored data. Three Indian scientists continue to work there.

Since the two main stations are at fairly close longitudes, the Soviet station more or less serves the purpose of redundancy.

A considerable amount of test equipment was designed and produced in India. The unique *thermovac chamber*, designed at the Bhabha Atomic Research Centre, and fabricated by the Electronics Corporation of India, was completed in just 6 months. It can maintain pressures as low as 10^{-6} torr and temperatures ranging from -100°C to +150°C, and was used for space-qualifying the satellite's sub-systems. The Control and Stabilisation Group produced a *spin table* for tests such as satellite spin, sub-system acceleration, etc. It operates at speeds between 0.3 rpm and 500 rpm, with speed-measurement through an electro-optical system.

The total Soviet contribution included some of the equipment and sub-systems requested by Indian scientists in view of the very tight schedule, the final checkout and integration with the launch vehicle, and the launch into orbit. The first flight model of the satellite was completed in just 26 months, While much of the basic effort has been Indian, a group of 15 Soviet experts headed by Academician B. N. Petrov, President of the Council of Intercosmos, have provided technical assistance. Director of the Soviet part of this project was Professor V. M. Khovtunenko, Corresponding Member of the Ukranian Academy of Sciences.

For the future, the Soviet Union has offered to cooperate with India in a number of fields including communications satellites. India has been keen to have a domestic communications satellite of its own and this could well become another joint Indo-Soviet space project.

SPACE REPORT

A regular monthly review of Space Events and Technical Trends

SPACE LINK

The Columbia movie "Marooned" may have helped to set up the Apollo-Soyuz Test Project, according to NASA historians.

In the film American astronauts are stranded in orbit, unable to return to Earth, their oxygen running low. In a bid to save them the Russians divert one of their spacecraft and a cosmonaut spacewalks with oxygen tanks in a bid to keep them alive until an American rescue ship arrives.

Visiting Moscow in May 1970 Dr. Philip Handler, President of the U.S. National Academy of Sciences, raised the need for a common Soviet-American rescue capability with top Russian scientists – including Academician M. V. Keldysh, citing the plot of the American film.

"That an American film should portray a Soviet cosmonaut as the hero who saves an American's life came to the Russians as a visible and distinct shock", says Dr. Handler. Two years later, at a dinner in Moscow, Keldysh confided that until they had met he had thought "All Americans have horns".

It was after describing that film, said Dr. Handler, that I broached the subject of a "common docking mechanism and all that it would make possible".

The Columbia film was based on a 1964 space novel of the same title by Martin Caidin, a long-standing B.I.S. member whose home is in Florida. Interviewed by *Time* magazine, Caidin comments: "It's damn nice to know that a writer can sometimes influence the course of history."

Meanwhile, leading Soviet and U.S. engineers have been enthusing over the high standards of engineering achieved in the joint effort. Vladimir Syromatnikov, team leader of the Soviet engineering group, declared that designers and scientists working in the field of manned spaceflight in both countries had amassed rich experience.

"Until today all spacecraft have used virtually the same type of docking system, with a probe and drogue as its main elements", he said. "This is the simplest technique ensuring easy and reliable coupling: the probe of one ship is inserted in the conical device of another ship and the two craft link up. Usually, the ship carrying the probe fulfills the main functions during docking, that is, is an "active" element. This technique called for equipping each pair of spacecraft with docking mechanisms of different design. Further progress in cosmonautics dictated the need to develop a more perfect, universal docking device of the active-passive type which would enable the link-up of any ships, not necessarily those launched by one country."

"During the first meeting of Soviet and U.S. specialists in mutual approach and docking, which took place in Moscow in the autumn of 1970, it was agreed to drop the probe-drogue arrangement system and to develop instead unified docking gear. In the new system docking mechanisms were to be situated on the periphery of the docking module, instead of taking up its central part which would then serve for crew transfer from ship to ship. The experts agreed in principle on the design of the docking unit as well as sizes of several key elements."

"The task of designing a new link-up mechanism was greatly facilitated by the fact that androgyneity was the underlying principle of the docking units used by Soyuz ships and Salyut stations. Their docking ring and hard docking latches, which had already been tested in flight, were accepted as a basis for the development of a new mechanism. This enabled researchers in each country to independently prepare the blueprints, build models and test them. The Soviet and American docking mechanisms were developed by stages, and each stage culminated with joint tests of newly built models. First, working scale-models were built, followed by life-size test models."

"In all trials conducted in the USSR and the U.S. the mechanisms were exposed to extreme mechanical conditions and extreme temperatures that are possible under unfavourable solar illumination. The mechanisms were docked at maximum speeds which would normally be avoided during the flight, and at low speeds, which are also indesirable. The units worked flawlessly."

"The joint tests of the flight models in the laboratory of the Institute of Space Studies in Moscow were of a different nature. Their purpose was to check the readiness of the docking mechanisms for flight, rather than to look for any shortcomings, let alone make design improvements. We actually docked the very mechanisms to be used in space."

Robert White, Syromatnikov's opposite number in the American team, spoke of the compressed timetable they had used in proving equipment in joint trials.

"In a laboratory of the Institute of Space Studies of the USSR Academy of Sciences," he said, "we had to demonstrate the compatibility of the flight docking models of the Soyuz and Apollo and to dock them the way this will happen in flight. In fact, what made these trials different from all previous tests was that here everything had to come off smoothly, without a hitch."

"Two docking units (the main and the backup) of the Apollo were linked up with each of the three Soyuz docking mechanisms. With each mechanism checked out in the active and passive role, a total of twelve dockings and undockings were carried out."

At the human end of the docking exercise there was also the language-barrier to be overcome.

From the outset of Apollo-Soyuz planning, there has been none of the "let-'em-learn-English" mentality. The differences between Germanic English and Slavic Russian were recognised early as potential stumbling blocks to efficient planning and operations for the joint space flight.

Nicholas Timacheff joined the ASTP staff at NASA's Johnson Space Center early in 1973 and tackled the task of organising the people and resources needed for hurdling the language barrier. Paris-born son of pre-revolution Russian emigres, Timacheff supervised the staff of interpreters, translators and crew language instructors at the Center. He speaks four languages in addition to Russian.

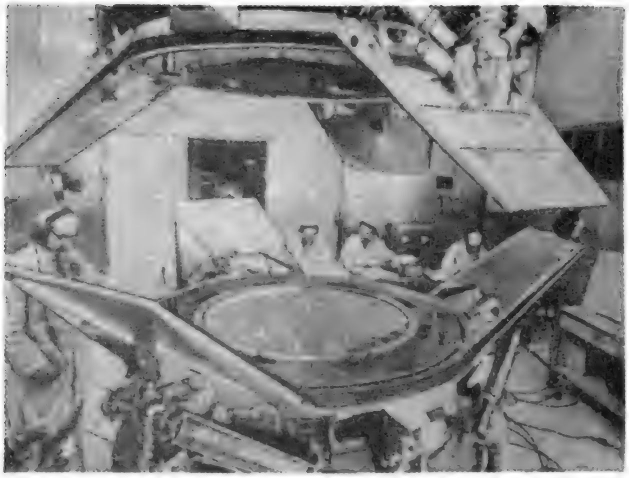
Of the 21 bilingual interpreters on Timacheff's staff, 10 were born in the Soviet Union and the rest were either of second or third generation Russian descent or were non-Russians who had learned the language to a high level of fluency. Regional dialects have posed no problems to the interpreters, who ranged from housewives to college professors. The interpreters adapted rapidly to the world of 'Space-Speak.'

The apparent complexity of Russian grammar, coupled with the proselyting of technological vocabulary from other languages, gives Russian a wide range of emphasis and subtlety of meaning, as well as an abundant capacity for warm human expression.

Proselyted words caused one interpreter some momentary embarrassment during a joint technical meeting on crew procedures when he interpreted a Soviet engineer as having said: "The crewman will then remove his diving suit and dry it before stowing it behind the Soyuz couch." In the pressure of the meeting, the interpreter had translated the Russian *skafandr* (spacesuit) into the definition of the French *scaphandre* (diving suit), from which the word was borrowed.

U.S. Astronauts' ASTP Patch; *below, left to right,* prime crew Thomas Stafford, Vance Brand and Donald ('Deke') Slayton at the Kennedy Space Center.

National Aeronautics and Space Administration



Above, testing ASTP docking mechanisms at the Gagarin Cosmonauts' Training Centre, Star Town.

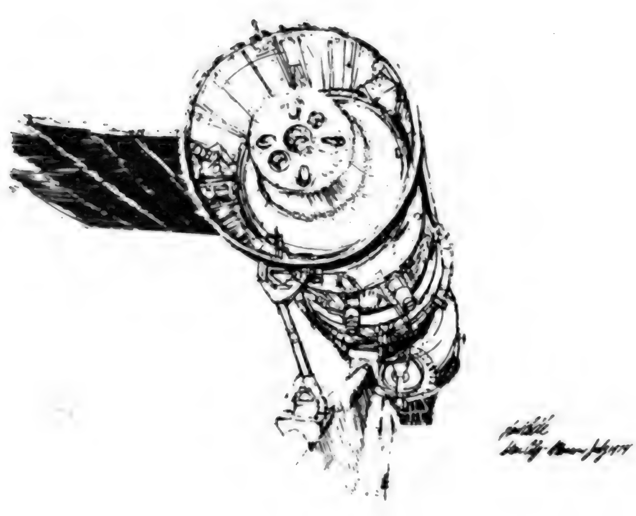
Novosti Press Agency

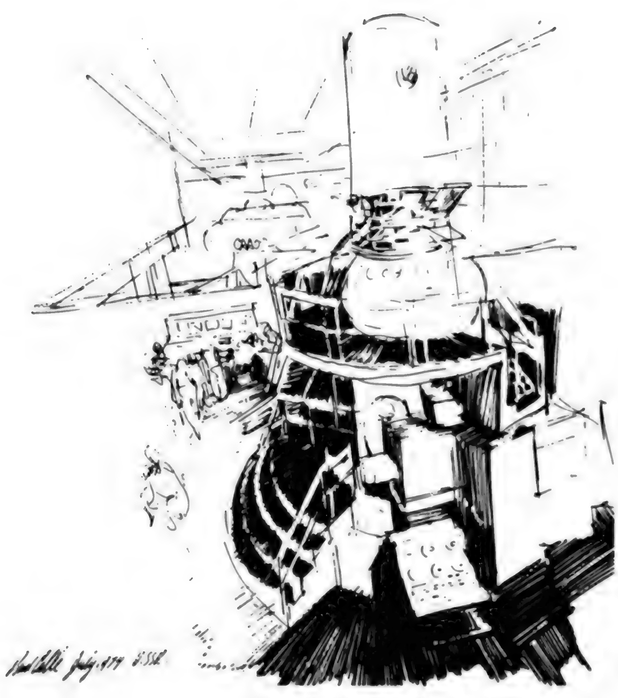
Right, Space buddies! Tom Stafford (US Apollo commander) and Aleksei Leonov (USSR Soyuz commander) inspect food cans and packages during a pre-flight training session at the Johnson Space Center earlier this year.

National Aeronautics and Space Administration

Drawings are by artist Paul Calle of Stamford who was invited by NASA to document astronaut-cosmonaut crew training for the Apollo-Soyuz Test Project. Both examples were done at Star Town. *Left*, Soyuz engineering mockup; *right*, test rig for docking mechanism.

National Aeronautics and Space Administration





While most interpreter duties in the months leading up to the July mission were in joint technical and planning meetings in Houston and Moscow, the interpreters had varied assignments during the actual flight. Sixteen of them were assigned to Mission Control, Houston where they worked in three shifts with the project technical director, flight director, communications technicians and public affairs commentators.

In addition to the interpreter staff, four Russian language instructors drawn from three American universities taught Russian to Apollo crewmen Thomas P. Stafford, Vance D. Brand and Donald K. Slayton for an average of six hours a day, with emphasis on conversational phrases peculiar to the experiments and joint operations planned for the flight. Soyuz crewmen Aleksei Leonov and Valeriy Kubasov were similarly instructed in English at Star Town.

ENERGY CONVERSION CLUE

Insect communications and animal eyes have provided a fundamental design clue for a NASA effort to investigate the properties of a proposed new type of solar energy converter for space and Earth-bound use. A basic research grant intended to develop the theory of the concept, called Electromagnetic Wave Energy Conversion (EWEC) has been awarded by NASA's Goddard Space Flight Center, to the University of Florida.

EWEC converters could have several applications. They might supplement the supply of electric power. They might be used in the area of early warning radar. Additionally, a better understanding of the function of electromagnetic antennae could be directly applicable to insect antennae, leading to electronic means of trapping insects to prevent crop and food destruction.

Robert L. Bailey of the University's Electrical Engineering Department will develop the theory for estimating the overall efficiency of converting the Sun's electromagnetic radiation by absorbing it in an array of insulated components and converting it directly to electricity. The EWEC absorber is functionally similar to insect antennae and to the retina of the eye.

Insects can communicate by the transmission and reception of infrared and other electromagnetic radiation or energy, using tiny antennae tuned to the proper frequency by nature's design. Once received, this energy is converted to electrical impulses. Similarly, electromagnetic radiation in the form of visible light is received by the eye and converted to electrical impulses by the retina.

One solar energy conversion device now used for special purposes on Earth is the silicon solar cell, an established device in the space programme. Sunlight impinging upon these semiconductor cells causes electrons to flow and thereby create direct current (d.c.).

The best solar cells presently have an equivalent space conversion efficiency of about 15 per cent (about 18 per cent on Earth). Thus, if 1,000 watts of sunlight fall upon one square metre (39 by 39 in.) of solar cell material, the resulting d.c. output is 180 watts on the ground.

The EWEC may have advantages over solar cells, but no reliable information is now available about its theoretical conversion efficiency. That is why this grant was awarded i.e., to better define the ultimate limitation of such an energy converter.

"The EWEC concept may offer a possible improvement over solar cells," said Harold J. Peake, head of Goddard's Aerospace Technology National Needs Office, which administers the EWEC grant.

"The $20,000, six-month grant is considered 'seed' money intended to establish the theoretical feasibility of the EWEC absorbers. We need to put it on a sound basis before proceeding with development of devices intended to demonstrate the concept," Peake added.

Professor Bailey invented the EWEC technique in 1968 while engaged in research at Goddard. It is protected by a NASA patent.

Based on his work at Goddard, Professor Bailey designed and built an early metal model of an energy collector which did not, however, function on solar radiation. His work took on a new significance when he discovered that his model resembled the design of insect antennae. This occurred when he later met Dr. Philip Callahan, an entomologist with the U.S. Department of Agriculture who has a courtesy professional appointment with the Institute of Food and Agricultural Sciences on the University of Florida campus. Dr. Callahan is a researcher in the Insect Behaviour Lab and will be a major contributor to the EWEC research effort.

Working on insect control techniques, Dr. Callahan's research has indicated to his satisfaction that insects utilise electromagnetic radiation waves in locating a mate, and perhaps in other activities such as hunting prey or homing to a food source. He has used the Scanning Electron Microscope to study the tiny antennae of the bodies of insects. This has enabled him to determine frequencies of electromagnetic radiation used by the insects.

Dr. Callahan's extensive pioneering scientific research with insect antennae was done at about the same time as Professor Bailey's work. "Since insects are 'programmed' to respond to certain environmental signals emitted at specific frequencies, we may be able to 'tune in' these frequencies with the aid of EWEC for selective insect control," said Dr. Callahan.

While hiking in the Philippine jungles of northern Luzon after World War II, Dr. Callahan witnessed insect control based on the emission of signals tuned to the large ghost moths. Without realising why, the natives there had learned that the moth, upon emerging from his pupal case, flies directly into the embers of a hot fire, making a tasty roasted morsel.

Research reveals that the wood used for the "lure" fires gives off a swirling and heated mass of hydrocarbons squeezed from the green wood by the intense heat. These hydrocarbons emit infrared frequencies, some of which are at the same wavelength as the mating signal from the sex scent of the female ghost moth. Wax candles attract moths in a similar manner.

ASTP MULTIPURPOSE FURNACE

Seven scientific experiments will be carried out in a multipurpose electric furnace during the ASTP mission to demonstrate the effects of weightlessness or crystallization, convection and other materials-processing techniques. They are aimed at improving these techniques for future applications.

The furnace to be used is an improved version of one used in the Skylab missions. It will be capable of higher temperature and more precise control of temperatures.

The equipment consists of four main parts: the furnace itself, mounted on the ASTP docking module wall; an electronic controller to maintain temperature levels in the furnace and provide controlled cooling to permit more constant crystal growth rates; an experiment cartridge which contains the sample materials; and a helium package to permit rapid cooling.

The furnace has three cavities for the processing of three material samples in a single run. It is constructed to provide three different temperature zones along the length of each sample cavity, with a hot end temperature selection available from 0 to 1,150 deg. Celsius (32 to 2,102 deg.F.). The furnace cool-down rate can be controlled at 0.6 deg. C. 1.2 deg.C. or 2.4 deg. C per minute automatically.

Each material sample will be contained in a cartridge which controls the actual temperature applied to the sample. The material cartridges will be returned to Earth for evaluation.

Principal investigator for the ASTP Multipurpose Electric Furnace System is Arthur Boese of NASA's Marshall Space Flight Center, Huntsville, Alabama; Bob Adams, MSFC, is project manager for the furnace development under contract to Westinghouse.

The seven ASTP experiments to be conducted in the furnace are:

(1) *Surface Tension-Induced Convection*, to determine if surface tension induced convection effects observed in oil films on two Apollo missions are present in liquid metals subjected to temperature gradients. Principal Investigator: Dr. Richard E. Reed, Oak Ridge National Laboratories, Oak Ridge, Tennessee.

(2) *Monotectic and Syntectic Alloys*, to investigate the effects of zero gravity on the mixing of molten metals in alloys. Principal Investigator: Dr. Choh-Yi-Ang, Northrop Corporation.

(3) *Interface Marking in Crystals*, to obtain an unambiguous analysis of the microscopic and growth behaviour of germanium in space. Principal Investigator: Dr. Harry C. Gator, Massachusetts Institute of Technology, Cambridge, Massachusetts.

(4) *Processing of Magnets*, to determine the effect of convection on the solidification processes and its relation to microstructure and magnetic properties. Principal Investigator: Dr. David J. Larson, Grumman Corporation, Bethpage, New York.

(5) *Crystal Growth from the Vapour Phase*, to determine the effects of zero gravity on single crystals grown from the vapour state. Principal Investigator: Dr. Harry Wiedmeier, Rensselaer Polytechnic Institure, Troy, New York.

(6) *Halide Eutectic*, to determine the solidification behaviour of an alkali halide eutectic composition under zero-gravity conditions. Principal Investigator: Dr. Alfred S. Yue, University of California, Los Angeles.

(7) *USSR Multiple Material Melting*, to determine the effects of zero-gravity on the metallurgic processes and the properties of a composite, of powder and of single crystals of compounds with markedly different specific weights. Principal Investigator: Dr. I. Ivanov, USSR.

MATERIALS PROCESSING IN ROCKETS

Materials processing experiments in near-weightlessness will be performed for the first time aboard unmanned sounding rockets in a new project to be managed by NASA's Marshall Space Flight Center at Huntsville, Alabama. Three flights per year are planned from 1975 to 1980. The project will use Black Brant 5-C sounding rockets, fired from the U.S. Army's White Sands Missile Range in New Mexico, and providing up to six minutes of low gravity (one tenthousandth of Earth's gravity) during the coast phase of the sub-orbital ballistic trajectory.

All scientific payloads will be recovered by parachute for ground analysis. NASA's Goddard Space Flight Center will provide launch and payload recovery services.

The goal of the sounding rocket programme is to expand upon the observations made during the Skylab missions where semi-conductors and metals were melted and allowed to solidify with little convection and sedimentation.

Significant improvements in material characteristics were found to be possible when processing was done in zero gravity. The rocket payloads will offer some improvements over the earlier experiment apparatus, including the use of active cooling instead of the time-consuming passive cooling on Skylab.

Analysis of the usefulness of only six minutes of low-gravity processing has revealed that a great number of materials can be solidified during rocket flight. Two meetings in recent months of 50 scientists from universities and industry supported development of the new project which has been under study for two years.

Industry representatives are increasingly interested in developing space-manufactured products – including metals, glass, electronic materials and pharmaceuticals – which are impossible to make on Earth. Research in space may also dramatically improve ground-based processes through better understanding of materials behaviour during melting, solidification and heat treating, without the masking effects of gravity.

The low-cost rocket missions will provide the only means of obtaining space-processing scientific data in near-zero gravity in the period between the Apollo-Soyuz Test Project in mid-1975 and Space Shuttle Flights in the 1980's.

The rocket experiments can be expected to increase participation by the user community, establish preliminary data for Space Shuttle missions and establish legal precedents for commercially funded materials experiments.

Using scientists' guidelines, the Marshall Center has modified off-the-shelf hardware or developed simplified equipment, including electric furnaces, for use on the research rockets. Devices being developed to process the flight experiments will allow materials to be melted and solidified while "floating" free of container walls. This processing technique, using acoustic or electro-magnetic fields to suspend the materials, should enhance material properties since contact with container walls, and its accompanying stress and contamination, is avoided – something not possible on Earth.

Each item of this payload equipment is designed for use on two or more missions. This reusability will help reduce costs. Experiments are now being selected from proposals

solicited from scientists in U.S. universities, industry, government and foreign countries. NASA's Office of Applications is sponsoring the project, which will use rockets already in NASA's inventory.

COMPUTING STELLAR SECRETS

The secrets of 'nuclear cooking' in giant red stars are being uncovered by a young Caltech-J.P.L. scientist using high-speed computer techniques. Deep inside these old giants, helium burns violently, erupting in flashes that astronomers have studied with increasing intensity. Now the chemical changes that occur with each flash have been simulated in a computer at a pace 500 times faster than previously possible by Dr. Juliana Christy-Sackmann, a Caltech astrophysicist.

A predominance of carbon is produced during this super-hot helium burning. The flash heat ranges up to 260 million °C (470 million °F) in some stars.

Dr. Christy-Sackmann's research, sponsored by the National Aeronautics and Space Administration, employs data obtained from high resolution infrared spectra made by Dr. Reinhard Beer, JPL astronomer at McDonald Observatory, Fort Davis, Texas.

"There's an awful lot of nuclear cooking going on out there," Dr. Christy-Sackmann says. "Some of these red giants are 1,000 times larger than the Sun, others are shedding mass and appear to be on the verge of falling apart."

Her report, culminating the first year of a continuing project for JPL's Planetary Atmospheres Section, stresses the role that convection of helium and hydrogen gases plays in fuelling red giants. The study eventually may shed light on the complex problem of stellar evolution.

While each red star flash may produce extreme interior disruption, surface changes in most cases appear to be comparatively minor. The release of energy from the interior varies enormously perhaps due, she says, to "convective zones that seem to come and go."

Dr. Christy-Sackmann hopes the project will reveal the true nature of the apparent linkup between the interior cooking region and the observable surface. "A convective tongue of helium seems to be driven through the layers of burning shells and outward toward the outer envelope of hydrogen. The hydrogen may also drop down so they overlap. This would give an extra energy kick to the old star," she reports.

Whatever the mechanism, the stellar furnace yields many elements. Atoms of light elements like lithium and of heavy metals like zirconium, yttrium and others have been found in red stars. The roles of the various elements in the life processes of a star may be revealed by further study.

Dr. Christy-Sackmann obtains what might be termed star profiles in a rather unusual way. By remote control from her Caltech office, she transmits data on each star flash to a CDC 7600 computer, said to be the fastest in the United States, at the University of California's Lawrence Radiation Laboratory, Berkeley.

The computer analyzes each flash in less than five minutes – "a saving of 500 times, both in time and money, over previous methods." A flash may represent anywhere from a fraction of a year up to a million years in the evolution of a red giant.

Of the hundreds of successive flashes taking place in a star, previous investigators found it possible to follow and analyze only a few due to the long computation time involved. The Caltech-JPL researcher plans to analyze hundreds – she has done 40 so far – of the violent helium shell flashes and the subsequent nucleosynthesis bubbling up in old stars.

One of the lodestars of the project is the changing super-giant known as *FG Sagittae,* which has been controverting most of the astronomical rules. This star, about 8,000 light years distant in the constellation of *Sagittarius,* has become steadily brighter and redder while producing more surface components for spectral observations.

FG Sge, as astronomers call it, is the only star found so far in which the chemical composition is changing "before our eyes, so to speak." Zirconium, yttrium and lanthanum are bubbling increasingly to the surface while other elements – iron, chromium and titanium – seem to remain at a constant level. However, lithium is the key element observers now are trying to verify.

Lithium, the lightest metal known, could ultimately provide the best clue to the interior structure and the deep convective mixing that goes on in giant stars, Dr. Christy-Sackmann adds.

SHUTTLE 'PASSENGERS'

Non-pilot members of Space Shuttle crews flying in the 1980's will qualify under much less stringent physical requirements than those demanded for today's astronauts. As many as 1,000 scientists, engineers and technicians may have the opportunity to carry out investigations in space aboard the Space Shuttle during the decade. NASA's Office of Life Sciences are to establish the medical criteria for selecting men and women scientists who will work and live aboard the Shuttle on missions ranging from seven to 30 days.

Mr. David L. Winter, Director for Life Sciences, says "The logical reason for different criteria is that mission safety rests very heavily on the pilots whose major responsibility will be flying the spacecraft. Scientists, however, will not have this same responsibility."

Relaxation of the strict astronaut medical standards for scientists is also more feasible because forces of acceleration during launch and re-entry on Shuttle flights will be only about 3g, much less than forces experienced by astronauts in earlier flights.

Scientist flight candidates will probably undergo centrifuge tests at this 3g level. Dr. Winter sees no barrier whatever to healthy women being among the scientists who will carry out the investigations on Shuttle Spacelab missions. In centrifuge acceleration tests made with 12 women volunteers at the NASA Ames Research Center, Mountain View, California, in 1973, no physiological problems were identified.

A prime objective in pursuing medical tests for scientists who may travel in space is to develop preventive measures against motion sickness. This is necessary to prevent scientists from becoming ill and unable to carry out their experiments.

Space medicine experts are not presently able to predict which individuals may be subject to motion sickness in space. Research is underway to develop devices to study an individual's visual, vestibular and muscular reactions – particularly during launch and re-entry conditions. Research will include use of anti-motion sickness drugs as a countermeasure to

motion sickness.

Dr. Winter concludes: "Our aim is to get the best qualified scientists that we can into space and to bring then back safely. Right now it is impossible to predict what size, shape, sex or age these scientists will be. Therefore, our approach must be to broaden the medical criteria as widely as we safely can."

HEAT-MAPPING SATELLITE

Scientists of the United States and other countries have been invited by NASA to propose investigations for use of data from the first mission of a series of small, low-cost spacecraft called Applications Explorers.

Applications Explorer Mission-A, scheduled for launch aboard a Scout rocket in late 1977 or early 1978, is designated the Heat Capacity Mapping Mission. A satellite weighing about 300 lb. (140 kg) will carry a single instrument to determine the thermal inertia of surface rocks and soil by measuring the difference in their temperature at the warmest and coolest times of day.

That information will be used to study the feasibility of mapping rock types in the U.S. and several other areas of the world. Such maps are expected to be useful in exploration for minerals and petroleum.

Other investigations are expected to study the feasibility of measuring soil moisture; the significance of plant canopy temperature in helping to determine the health of growing plants; the mapping of natural and man-made thermal effluents in bodies of water; and the use of frequent mapping of snow fields for predicting water runoff.

The spacecraft will fly a north-south orbit at an altitude of about 370 miles (600 km) and pass over each local area in the U.S. at about 1:30 p.m. and 2:30 a.m. Its radiometer will view a swath of Earth's surface 435 miles (700 km) wide with a spatial resolution of 1,650 by 1,650 ft. (500 by 500 metres).

No tape recorder can be carried because of weight limitations, so the spacecraft will be limited to transmitting data when within range of a ground station. Stations are located at Fairbanks, Alaska; Goldstone, California; Rosman, N.C.; Madrid, Spain, and Orroral, Australia.

BETTER SPACECRAFT MEMORY

"Bubble" technology may sound like a new development in the soap industry, but, in information sciences, it refers to a recording technique expected to improve the reliability of data storage systems aboard future NASA spacecraft. The new technology will also provide improved high-capacity memory storage for both spacecraft and commercial computer systems.

Microscopic magnetic spots called bubbles are substituted for magnetic tape in spacecraft recording instruments.

The bubbles exist in special magnetic crystals which are sliced wafer-thin. A thin pattern of magnetic material is overlayed on the crystal so the bubbles can be moved in a controlled fashion to perform specific computer logic functions. The completed crystal is then subdivided into quarter-inch rectangular sections called chips.

Under contract to NASA's Langley Research Center, Rockwell International Corporation has developed what is believed to be the largest integrated memory element ever fabricated. The recorder at Langley has a 102,400-bit single chip capacity. Bit refers to a binary digit, the smallest unit of computer-coded information.

The memory element is designed for use as a basic building block in a 100-million-bit solid-state data recorder. The recorder under study at the Langley Center is about one-third the size of a conventional magnetic tape recorder, weighs about half as much and requires only half the power.

The bubble memory recorder has no moving parts, a distinct advantage over magnetic tape recorders. When a tape breaks, the entire tape recorder stops working. The solid-state bubble recorder avoids this deficiency. It is segmented so, if a single part breaks down, the unit will continue to operate at a reduced capacity.

INTELSAT 4A CONTRACT

Britain's export stake in expanding world television and telephone communications has won a £1.5 million boost with a new order for satellite sub-systems placed with British Aircraft Corporation's Electronic and Space Systems Group by the Hughes Aircraft Company in the United States.

BAC will manufacture three sets of systems for *Intelsat IV A* global communications satellites, latest development of the well-established orbital relay station, which can handle virtually double the traffic of earlier models – up to five thousand telephone conversations or twelve TV channels.

This is the fifth commercial space contract BAC has received from Hughes for major sections of communications satellites and, when the latest is completed in 18 months time, the group will have made a total of 16 sets with a value to date of over £6 million ($15 million).

Work is undertaken in a special "clean" spacecraft assembly facility at Bristol, completed in April 1970, for construction of communications satellites to carry global telephone and television traffic.

Typical of the assemblies BAC will manufacture for the *Intelsat IV A* are: structures-spun structures, booster adapters and separation sub-systems and: integration hardware-wiring harnesses, battery packs and solar arrays.

To date the company has won contracts from Hughes for sub-systems for the *Intelsat IV*, six of which are in service around the globe; sub-systems for *Comstar 1* satellites to be used for internal United States communications and an earlier order for *Intelsat IV A* sub-systems. All such programmes are directed by the Communications Satellite Corporation (*Comsat*) as manager for the 86 nations in the International Telecommunications Satellite Organisation.

DISCOVERIES OF ARIEL 5

The discovery of immensely powerful sources of X-rays at the centre of the Galaxy by the UK Ariel 5 satellite has been reported by scientists of Mullard Space Laboratory and Birmingham University. When X-ray telescopes aboard the satellite were first aimed at the galactic centre last November, there was nothing to be seen. But when the region was observed again in February, it was the second brightest X-ray source in the sky.

Earlier, Ariel 5 had discovered a new X-ray star which flared up to its brightest on Christmas Day 1974 before dimming away and flaring up again in a regular cycle with a period of some 6¾ min. The periodicity was consistent neither with known properties of pulsars nor binary stars.

X-ray stars were first discovered from rocket flights in the 1960's (since the X-rays concerned are unable to penetrate the atmosphere, this could not be done from the ground), but the first reasonably extensive catalogue was made only in 1970/71 by the US satellite Uhuru. Over 160 sources were listed then though it is known that transient sources which last only a few months are common and so one of the requirements for Ariel 5 was to re-survey the sky to find what sources exist now. The sources include objects inside our Galaxy and other galaxies though so far only about one fifth of them are identified with astronomical objects. Many of the Galactic sources have a powerful emission of energy – up to nearly one hundred thousand times the total energy emission of the Sun. They seem usually to be associated with the final stages of evolution of a star when it collapses into a tiny star – white dwarf, neutron star or black hole – possibly after a violent explosion or supernova when part of the material from the star is ejected into the space around it. The only other means of studying neutron stars at present is as pulsars, yet they are of great interest both to astronomers and to physicists, since they are composed of nuclear, not atomic, material. Black holes represent the most extreme stage of collapse, and no other means by which they might be studied is known.

The extra-galactic sources seem to be of two kinds – those associated with the nucleus or central core of active ("exploding") galaxies and those associated with large clusters of galaxies. In the latter case it seems likely that the X-rays originate in a large gas cloud surrounding the central galaxies in the cluster, in which case the gas cloud must be at a temperature of the order of ten million degrees centigrade.

So few X-ray sources have been identified, or studied in any detail, that explanations of the sort just given must be very tentative. Ariel 5 was only the second satellite to be devoted to X-ray astronomy, and has several "second generation" experiments. Apart from Ariel 5 and Uhuru, only three isolated experiments of this type have been launched on any satellite, including the UK experiment on the Copernicus orbiting astronomical observatory.

GAGARIN'S LAST FLIGHT

The last days of Yuri Gagarin – the first man to orbit the Earth in space – are recalled in a recent issue of the Soviet publication *Aviatsia i Kosmonavtika.* The article, by General Andrian Nikolayev and Colonel Nikolai Kopylov, comments warmly on Gagarin as a man "far ahead of his times". The authors confirm that at the time of his death in a flying accident he was training as back-up to Vladimir Komarov for the first manned test flight of the new Soyuz spacecraft.

On 27 March 1968, Gagarin had to take a refresher course in flying technique after a long break and then resume training flights in a two-seat Mig-15. Like American astronauts, cosmonauts fly not only to keep themselves in trim as pilots, as most of them are fighter pilots, but also to facilitate their work in space.

During his pre-flight training in the classroom Gagarin sat at a desk in the front row. He had his flight map spread out and listened to reports by the navigator, the flight commander and the meteorologist and made notes.

At 10.19 hr. on 27 March, with Colonel Vladimir Seryogin, commander of an air unit, Gagarin taxied out to the air strip and received permission to take off.

Several minutes later the loud speaker at the control tower gave the information: "Mission fulfilled!" After receiving permission to return, Gagarin confirmed the approach path: "Understood, complying...."

Those were Gagarin's last words, and nothing then seemed to portend a tragedy, say the authors. But as time passed, watchers on the ground became apprehensive. There was no communication from Gagarin and Seryogin, the clock kept counting the minutes, but their plane did not appear over the airfield.

Aircraft and helicopters took off on a search mission, and then came the first report: "I can see the place where the plane crashed. I can see smoke and traces of an explosion 2½ km south-east of Novosyelovo village."

The crew had been killed instantly. The time of the crash 10.31 – was shown by the hands of a watch, or more precisely marks on the face of the watch where the hands had been.

IMPROVED SKYLARK CONTROL

A new Ferranti-designed control system for high-precision attitude reference of Skylark payloads has been announced. The Inertial Systems Department of Ferranti Limited in Edinburgh has received a contract from the Science Research Council to supply two of the inertial attitude reference units together with associated ground control equipment.

Previous Skylark rockets have achieved attitude control using Sun or lunar sensors together with an associated gyro stabilisation system, but, says Ferranti, this type of attitude control constrains the rocket launch times to the availability of the optical reference.

The Ferranti system for Skylark is designed to provide a high-precision attitude reference so that the rocket can be pointed accurately in a desired direction in space during the stage of flight when scientific observations and experiments are made. The forthcoming programme of SRC scientific experiments will be concerned primarily with measurement of X-ray emission from space sources and an X-ray survey of the southern skies.

Ferranti's Digital Inertial Navigation System has already been selected for a wide variety of aerospace systems including the MRCA and the satellite launcher Ariane, after earlier experience with the guidance systems of the Black Arrow and ELDO satellite launch vehicles.

SPACE TO WASTE

Dr. Rocco Petrone, the former Associate Administrator of NASA, has joined the National Center for Resource Recovery as President and Chief Executive Officer. After playing a major role in the Apollo and Skylab programmes, Dr. Petrone will help develop techniques to recover materials and energy from solid waste.

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LANDSATS – SPACECRAFT EXPLORING EARTH

By Robert Edgar

A major aim of the BIS Development Programme announced in April (*Spaceflight* May 1975 p. 162) is to expand knowledge of Space techniques which may be expected to play an important role in the future development of our civilization. As we look towards the 21st century, mankind has a clear obligation to eliminate hunger, poverty and disease, to educate all people, to attack pollution at its source, and to conserve precious natural resources. Not long ago many people considered investment in space technology wasteful of human resources; and yet today major tools in the battle for human survival are being forged in space laboratories, and a new spirit in international affairs is being formulated which shows a path away from narrow materialistic interests and destructive trends in society. Last year, in three major articles, we examined the first pioneer experiments in direct-broadcasting TV satellites opening the doors of education to remote communities in rich and poor countries alike. The present article describes another dramatic development, the remarkable Landsat remote sensing platforms which are amassing experience for future operational systems. Such instruments, which know no frontier, could have an immense impact on future social evolution.

Kenneth W. Gatland

Introduction

NASA Administrator Dr. James C. Fletcher said recently: "If I had to choose one spacecraft, one Space Age Development to save the world, I would pick ERTS and the satellites which I believe will be evolved from it later in this decade." He was enthusing over the first of two Earth Resources Technology Satellites – renamed Landsats on 14 January 1975 – which has impressed the scientific community in a way the Apollo missions failed to do. Hundreds of investigators around the world examine the returns from the satellites and often learn things of immediate practical benefit. ERTS 1, now Landsat 1, was launched on 23 July 1972 and attained a near-polar orbit of 903 x 921 km altitude, inclined at 99.12 deg. to the equator and period 103.27 min. Ita basic objective was to evaluate technology involved in the remote sensing of Earth resources, to blaze a trail for more advanced systems; but was so unexpectedly successful that it rapidly achieved the status of a fully operational prototype. It was followed by the virtually identical 953 kg Landsat 2 on 22 January 1975, which entered an orbit of 906 x 918 km x 99.09 deg. inclination and period 107.28 min. The orbit is Sun-synchronous, meaning that whenever the spacecraft passes over a given latitude the local time is the same, e.g. 09:30 at the equator.

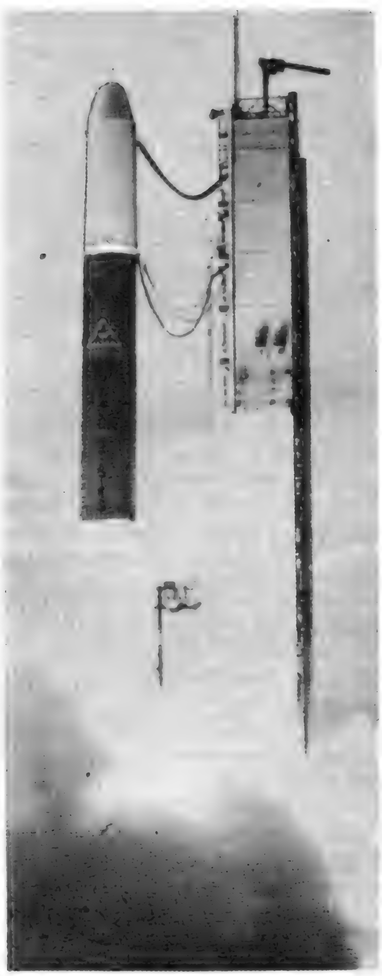
Both satellites were launched by two-stage thrust-augmented Delta 900 DSV-3N-1 rockets from the SLC-2W complex at the Vandenberg Air Force Base, California. This type of Delta is nicknamed the "straight eight" as each stage is exactly 8 ft. in diameter. The first stage, a modified Thor booster, has nine Thiokol strap-on solid propellent motors which are jettisoned 100 seconds after ignition (T + 100s). The second burn of the 2nd stage, after a 2310 second coast, ends at T + 3480s and the Landsat spacecraft separates 170 seconds after cutoff. The ascending node on the first orbit (Rev. 1) begins at T + 3684s with the subspacecraft local time at 21:30, and the Alaska tracking station acquires the spacecraft at T + 5274s.

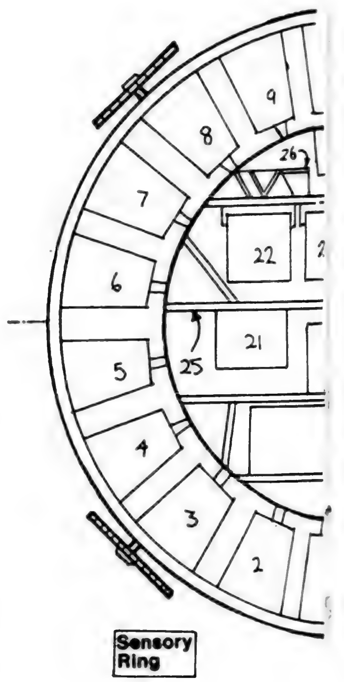
Landsat Objectives

The specified requirements of the Landsat system are to provide: (1) Multispectral photographic and digital data of a large scene in user-orientated quantities; (2) Repetitive land and coastal observations at the same local time; (3) Image overlap in direction of flight; (4) Image sidelap from adjacent orbits; (5) Image location to better than 2 nautical miles; (6) World coverage in less than three weeks; (7) Operating spacecraft life of at least 12 months; (8) Facilities for processing and distributing data to investigators is useful form and on a timely basis. Requirement (6) emphasises one of the greatest advantages of Landsat – the entire globe passes under the scrutiny of each spacecraft's scanners every 18 days (every 251 revs. at 14 revs. per day) permitting a very close watch to be kept on short-term variations in conditions on Earth. The nth rev. coverage overlaps with that of the (n+14)th. The (n+1)th rev. coverage lies 2875 km to the west of the nth.

Landsat 2 was successfully launched by a 'straight-eight' Delta at 12:56 EST on 22 January 1975 and achieved a 915 km circular orbit.

NASA





The Spacecraft

The General-Electric-built spacecraft are direct descendants of the 5 Nimbus weather satellites, and many of the service subsystems have undergone little alteration in the transition. The spacecraft each accommodate up to 530 lb. of payload with a packaging volume of 37 ft^3. An Earth-viewing area of 15 ft^2 is available on which sensors are mounted. There are four basic structural elements:

(1) *The Attitude Control Subsystem (ACS).* This is the uppermost component providing unobstructed, exposed mountings for the solar paddles, Sun sensors, gas nozzles and horizon sensors; and a protective housing for pneumatics and mechanical drives.

Spacecraft attitude errors are measured by the ACS sensors and their processed output signals fed to the command torquing mechanisms to make corrections. The ACS can acquire any reference attitude at angular rates of 5 deg/s about the body axes, with pointing or tracking accuracy to the reference orientation of ±0.7 deg from each axis.

The Solar panels can be independently rotated about one axis (y) for Sun tracking accuracies of between 10 and 30 deg, varying with the yaw error.

These drawings show the Landsat spacecraft and launch vehicle, the TAD (Thrust Augmented Delta). (1-18 are the sensory ring bays) 1. Wideband power supply and amplifier, VIP memory; 2. Battery; 3. Wideband power amp and frequency modulator; 4. Payload Regulator; 5. Battery; 6. Power control; 7. RBV-2 electronics, VHF receiver; 8. Clock; 9. VHF receiver, battery; 10. RBV-1 electronics; 11. USB equipment; 12. VHF transmitter and RBV-3 electronics; 13. Battery; 14. Battery, VIP formatter; 15. MSS multiplexer, Battery and VIP reprogrammer; 16. VIP coder, Battery; 17. VIP, memory, battery; 18. VIP memory sequencer; 19. and 20. WBVTRs; 21. NBTR; 22. RBV-2; 23. RBV-1; 24. RBV-3; 25. cross beam assembly; 26. RBV support structure; 27. Quadriloop antenna; 28. Solar Paddle (supplies power during the 70% daylight part of orbit); 29. VHF command antenna; 30. ACS; 31. -y Solar Paddle; 32. VHF Quadriloop antenna (4); 33. Sensory Ring; 34. Wideband antenna; 35. USB antenna; 36. MSS; 37. RBVs; 38. Wideband antenna; 39. Attitude Measurement Sensor; 40. Truss Structure; 41. OAS nozzle (3); 42. Payload Shroud; 43. Delta 2nd stage – powered by a Lunar Module engine; 44. Thor booster, Delta 1st stage; 45. Strap-on boosters. (Note insulation is omitted from the lower surface of the spacecraft drawing.)

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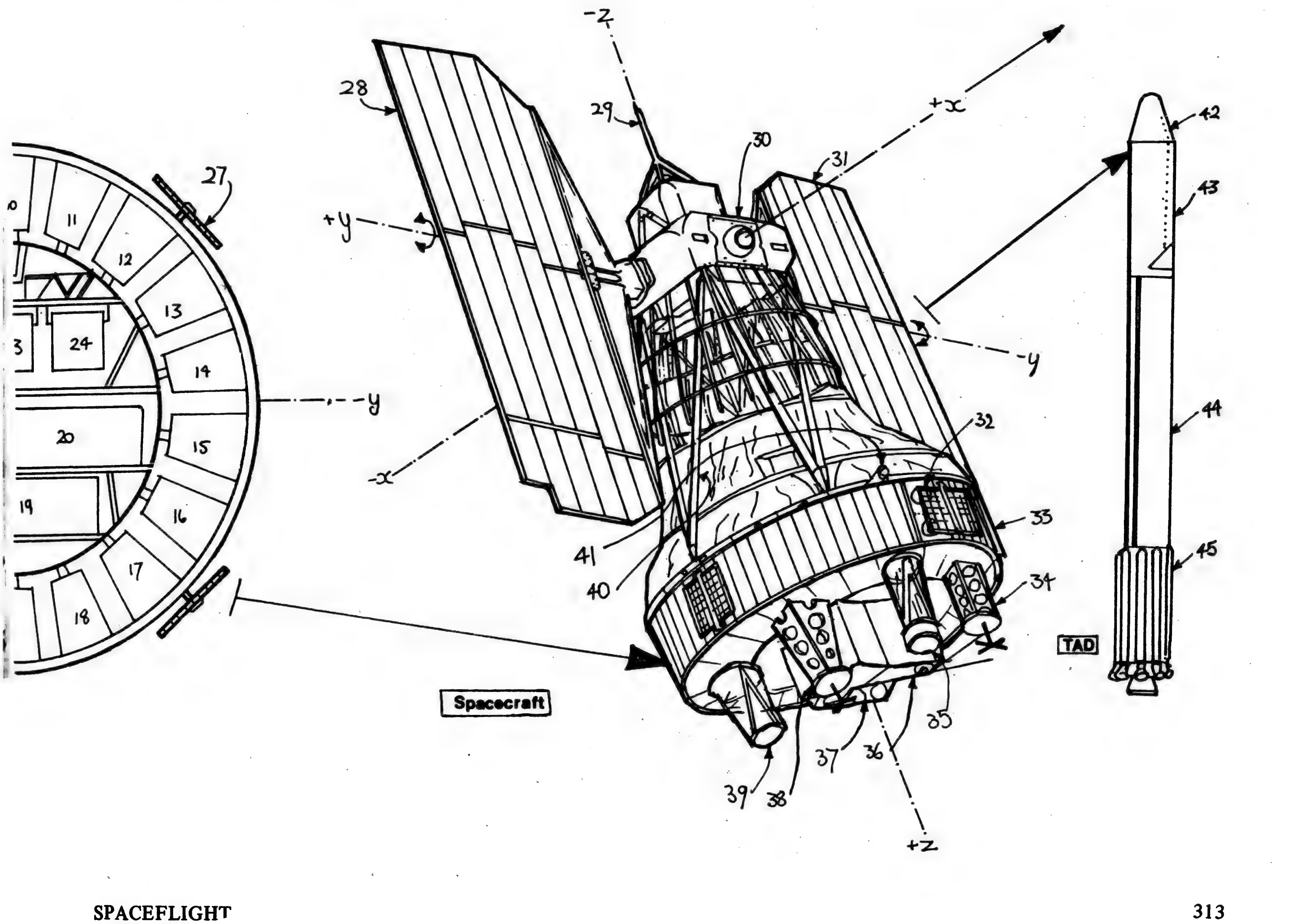
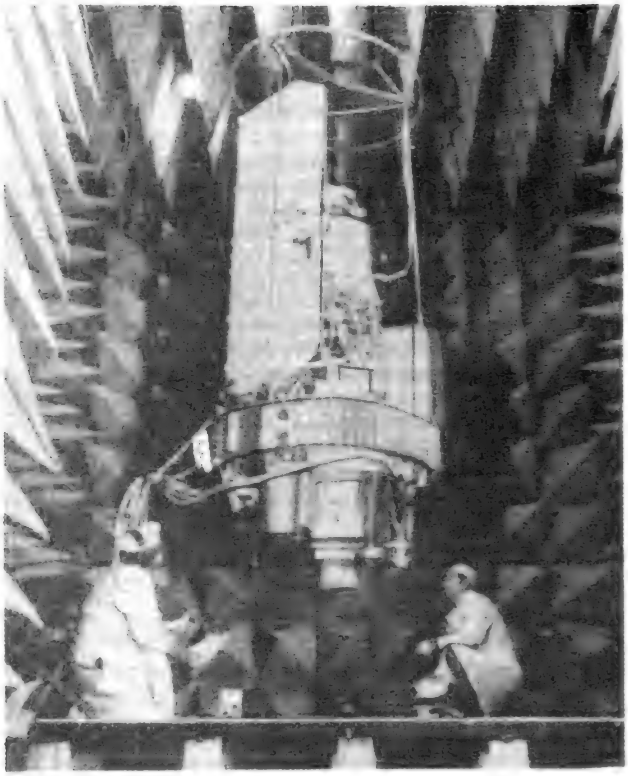




A Landsat spacecraft undergoing final antenna impedance and RF compatability testing in an anechoic test chamber.

General Electric

Three axis torquing is provided by hermetically sealed two-phase servo-motor reaction wheels. Power and commands to the ACS are routed through harness interface panels from the Sensory Ring.

(2) *The Solar Array Paddles.* These are attached to shafts projecting from the ACS. At launch they are folded along their long axes to fit in the Sensory Ring envelope, and are secured to the truss structure by a latch mechanism. Each paddle is covered by N on P silicon cells with an 11.5% efficiency, providing about 550 W per spacecraft at 35°C.

(3) *The Truss Structure.* A tripod connection between the ACS and the Sensory Ring, the structure supports the command antenna and auxiliary load panel.

(4) *The Sensory Ring.* This is the 'business end' of the spacecraft, a torus composed of 18 rectangular module bays 32cm deep. These bays contain the electronic equipment and battery modules. The lower surface of the torus provides a mounting area for payload and antennae. In the centre is a crossbeam assembly supporting two Wideband Video Tape Recorders (WBVTRs), three Return Beam Vidicon (RBV) cameras, two Narrowband Tape Recorders (NBTRs), the Solar Paddle unfold timer, the Power Switching Module and the Telemetry Conversion Module. The upper plane of the Ring supports the Orbit Adjust Subsystem (OAS), the WBVTR electronics and the Magnetic Moment Assembly. The lower plane provides mounts for the Multispectral Scanner (MSS), the Attitude Measurement Sensor, the Data Collection System (DCS), two wideband antennae and the unified S-band (USB) antenna.

The WBVTRs record, store and playback either RBV or MSS data during remote sensing operation, each with a capacity of 30 min. of 3.2 MHz video analog data from the RBVs or 15 Mbps digital data from the MSS. Data are recorded by a wheel carrying 4 recording heads rotating across the 5 cm wide tape moving at 30.5 cm/s (during both recording and playback) with a total usable tape length for each recorder of 548 m. Also associated with the wideband transmission equipment are two 20 W travelling wave tube amplifiers and high voltage supplies. The data are transmitted to ground receivers by two 20 W S-band FM antennae which accept real-time or taped data after signal processing by a video controlled oscillator – 2,265.2 MHz for one antenna and 2,229.5 MHz for the other. Each antenna is circularly polarised with a dB gain ± 60.6 deg. off the spacecraft principal axis.

The Narrowband Telemetry and Command Subsystem (NTCS) collects and telemeters spacecraft and payload housekeeping data, and receives and implements commands from NASA's STDN network.

The downlinks are through VHF and S-band frequencies compatible with various remote STDN stations. It is also capable of carrying narrowband taped data at a record/playback ratio of 1:24. The USB downlink contains several types of data transmitted simultaneously on a 2287.5 MHz carrier. The NBTR data are dumped on one of four subcarriers (597 kHz) with phase shift keyed modulation.

The telemetry equipment samples the analog and digital data from spacecraft subsystems and encodes it in a pulse code modulated format. 918 telemetry points (582 analog: 16 10-bit digital words); and 320 1-bit binary words) are sampled at rates between once in 15 seconds and 5 per second. The telemetry data matrix has 20 columns each 80 rows deep. Two columns are used for synchronisation, one for time, one for minor frame identification and the remainder for the sampled inputs.

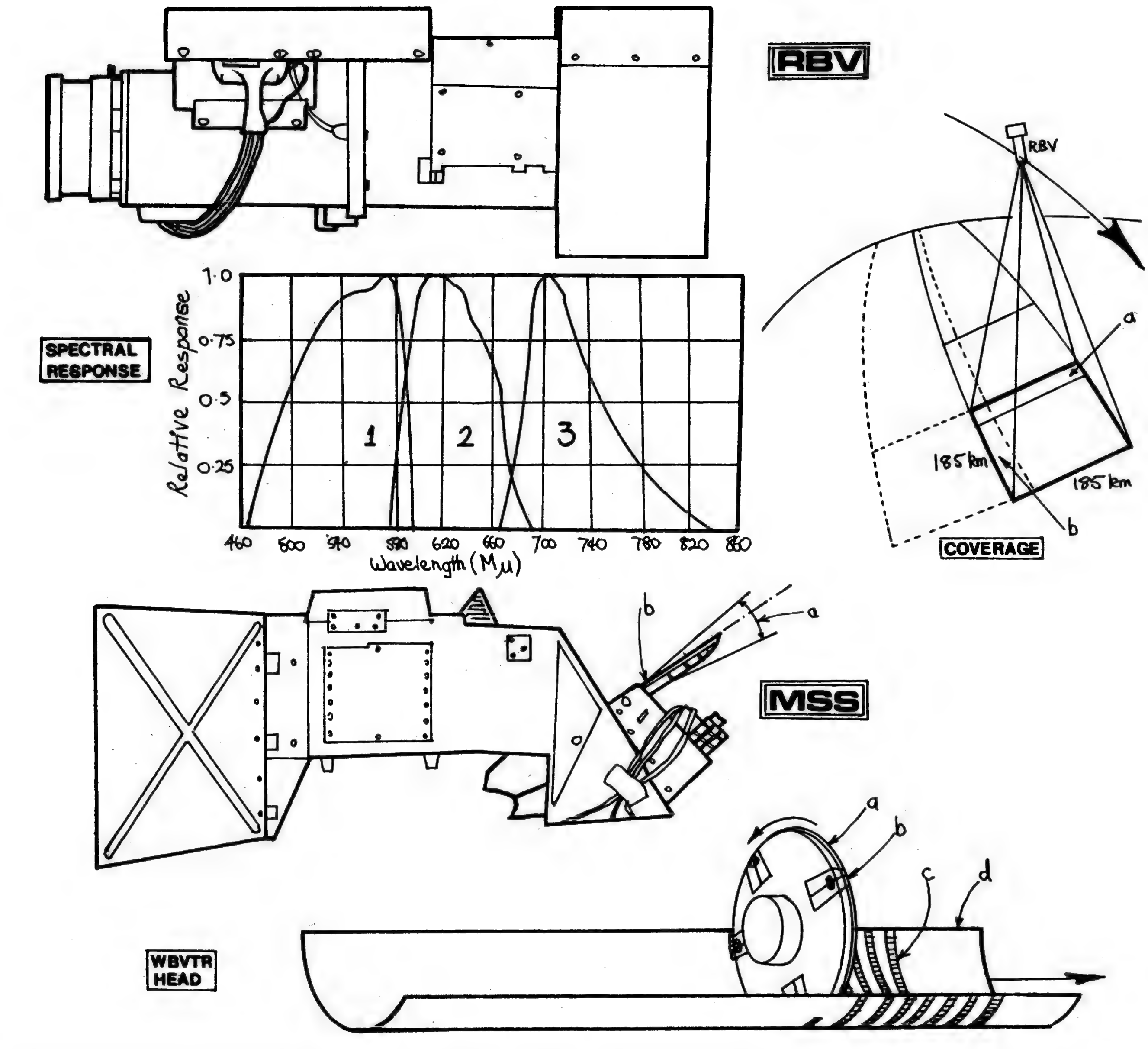
An important element of the NTCS is the Versatile Information Processor (VIP) which performs the sampling and encoding operation for real-time transmission or recording by the NBTRs. These can tape up to 210 minutes of 1 kbps of data for playback at 24 kbps. Telemetry links are the 2287.5 MHz USB or a 137.86 MHz VHF carriers.

The OAS is used to obtain the precise desired orbit after insertion and to maintain the characteristics of the ground coverage pattern. It is a monopropellent hydrazine-fuelled system with three rocket engines operating at an exhaust temperature of about 1800°C. It has 30.4 kg of hydrazine, and its thrust range is from 4.3 N to 1.33 N at the end of its life. The maximum total impulse it can provide is 38,699 Ns, with engine firing durations of from 1.0 to 24,000 seconds.

The Power Subsystem provides -24.5 V dc ± 0.5 V to the spacecraft. It has 23 Nickel-Cadmium series storage cells each with a 4.5 amp- hr. capacity, with power supplied by the solar cells.

Payload

The Landsat observatory payload consists of a Return Beam Vidicon (RBV) camera subsystem, a Multispectral Scanner Subsystem (MSS) and a Data Collection Subsystem (DCS).



These drawings illustrate the Landsat payload and its operation. The RBV camera shown is typical of the 125 mm focal length vidicons, and the spectral responses of the filters used in the three cameras below. The overlapping picture coverage is seen to the left. Overlap (a) with adjoining photos varies, the least value being 18 km at the equator; overlap (b) also varies according to latitude and is 14% at the equator. The MSS scans a continuous strip 185 km wide, corresponding with the 185 km square overlapping sequence of images from the RBV's.

The MSS is shown in operation, with the mirror oscillating through a total angle (a) of 5.98°. Below the WBVTR tape operation is shown, recording image data from both the RBV and MSS. The transverse motion of the head greatly increases the effective tape speed. About 120° of tape (d) curls up against the headwheel (a) with the video heads (b) recording tracks (c).

RBV Subsystem. This contains three vidicon cameras, similar except for their spectral response. All three are aligned to view a 185 km (100 nm) square footprint. When the shutters are opened, for exposures of between 4.0 and 16.0 ms, the photosensitive surfaces store the images, and for the last 10.5 seconds of the 25 second picture-taking cycle the surfaces are scanned. The video data interval for each camera lasts for 3.3 seconds. The pictures are composed of 4,125 lines (compared with 625 lines on a typical TV), scanned at 1,250 lines/sec. in the order camera no. 3, no. 2, no. 1

Three modes of operation are selectable by ground command: (i) continuous operation, where each camera takes a photo every 25 sec; (ii) single cycle, where one 25 sec. cycle is performed and the system 'held' until the next command; (iii) a calibration mode where known intensities from an internal source are exposed. Reseau patterns are inscribed on the photosensitive surfaces to aid in photogammetric measurement. This helps offset the effect of centering errors – the

most serious internal distortion of the vidicons – which can result in 0.75% positioning error. The RBV resolution is about 175m; signal to nose ratio 33 dB for cameras 1 & 2, 30 dB for camera 3.

MSS. The Landsat MSS is a 4-band scanner imaging the Earth in the four spectral bands simultaneously. It scans a continuous cross-track swath 185 km in width, corresponding with the area viewed by the RBVs as a series of overlapping squares. Effectively a Cassegrain telescope, the MSS has an oscillating mirror swinging ± 2.89 deg. from its rest position at a frequency of 13.62 Hz, with a field of view of 11.56 deg. Each spectral band is covered by six detectors, making a total of 24 detectors. Band 1 (Green light) is 0.5 to 0.6 μm; Band 2 (Red) is 0.6 to 0.7 μm; Band 3 (Infrared) 0.7 to 0.8 μm; and Band 4 (Infrared) is 0.8 to 1.1 μm. The infrared region was covered in two sections in the hope of improving knowledge of plant disease. Composite images of Bands 1, 2 and 3 or 1, 2 and 4 are sometimes constructed.

Bands 1-3 use photomultiplier tubes as detectors, Band 4 uses silicon photodiodes, all four employing fibre-optics to carry the image points. The video outputs from each detector are sampled and commutated once in every 9.95 μs, multiplexed into a pulse amplitude modulated stream and encoded. The active scan is from West to East and the flyback (analogous to that is an oscilloscope) from East to West. During the flyback the shutters are closed and a light source projected onto the fibres, introducing a 9 ms callibration wedge into the data stream. Uncorrectable sources cause a cumulative positional error on the images of ± 26 m, compared with the MSS maximum resolution of 75 m.

A fifth sensor set operating in the 10.4 to 12.6 μm range in the infrared was originally planned for Landsat 2, which would have required passive cooling, but was omitted.

DCS. The sensors for this final element of the payload are not on the spacecraft but scattered across the U.S. and Canada. The DCS acts as an intermediary between remote Data Collection Platforms (DCPs) and a ground receiving station. Up to eight environmental sensors are connected to each DCP, which transmit the data through the DCS to one of three prime receiving sites: Fairbanks, Goldstone or NASA's Network Test and Training Facility. A 1.024 MHz subcarrier of the USB link is used. At least one message from each of the over 200 DCPs is relayed every 12 hours.

Ground Information Handling

Information processing activity is focussed on Building 23 of the NASA Goddard Space Flight Center (Greenbelt, Maryland), the Ground Data Handling System, GDHS, facility. It consists of the Operations Control Center (OCC), which is the centre for all communications with the two Landsat satellites, scheduling activities 24 hours a day; and the NASA Data Processing Facility (NDPF) which processes all sensor data and disseminates large quantities of it in the form of film imagery, computer tapes and DCS tapes, cards, and listings. Bulk RBV and MSS images are distributed as 70 mm B & W negatives and positives; 240 mm colour positives and paper prints, and on 7- and 9-track computer-compatible tapes; punched cards, 7- and 9-track digital computer tape and computer listings are used for dissemination of DCS data. The 7-track computer tape has 556 bits per inch, 9-track 800.

The bulk processing system compensates for: geometric distortion due to spacecraft platform instabilities, systematic errors caused by RBV vidicon distortion and radiometric errors in each RBV and MSS spectral band. The Photographic Processing Facility (PPF) produces 240 mm triplets of negatives for generating colour composites. The PPF also produces negative microfilm masters of RBV and MSS images and prints positives for shipment to investigators.

Landsat C

A third Landsat spacecraft, Landsat C (to be designated Landsat 3 on reaching orbit) is scheduled for launching late in 1977 from NASA's Western Launch Operations Division. It will follow a similar Sun-synchronous path, but will carry "improved sensors to collect more detailed data than its predecessors."

Design Life Exceeded

At the time of writing, Landsat 1 is approaching the end of its second year in orbit – having had a design life of 12 months – and has suffered only the most minor malfunctions: a relay failure in the RBV system, which has slightly reduced the flexibility of its operation; a power supply anomaly with one of the Wideband Video Tape Recorders, now diagnosed and remedied; and the pitch reaction wheel is misbehaving, though careful use should prolong its life. The mirror in the ruggedly built MSS has oscillated back and forth 90,000,000 times, covering a cumulative area of some 1,750,000 square miles. Information from nearly 2,000 sensors is relayed daily by the spacecraft's DCS. How is this mass of data used? What benefits are derived?

Landsat: Primary Investigations

The Landsat 1 primary investigations involve 320 investigators, working in 10 broad areas, and the follow-on studies 51 investigators in 35 countries from Australia to South Vietnam and Zaire. Both US agencies: NASA, the US Geological Survey (USGS), the National Oceanic and Atmospheric Administration, the US Department of Agriculture and others, and some 35 external organisations are participating in this follow-on phase. Parallel to this will be a number of experimental demonstrations of the potential of multispectral photography in resource management. The most notable of these is the Large Area Crop Inventory Experiment (LACIE) which will try to determine whether Landsat imagery, processed by computer, can enhance the accuracy of major crop forecasts. US Secretary of State Henry Kissinger, speaking before the 1974 UN World Food Conference in Rome, said LACIE was a "promising and potentially vital contribution to rational planning of global production." Computers can already analyse tapes of MSS data directly and identify crops with errors of 5% or less and potentially 0%, say investigators.

Four countries outside the US are building Landsat processing facilities: Canada, Brazil, Italy and Iran. On 26 January 1975 it was announced that Zaire will build the first African station (ERTS-Zaire) near Kinshasa, capable of producing computer tapes and photographic material. Canada already has an operating facility at Prince Albert and plans to build another near St. Johns, Newfoundland. The Brazilian station is located at Cuiaba; the Italian and Iranian stations are still at an early stage. There is an emphasis on foreign participation by the US – images are available at nominal sums to anyone who asks and developing countries, in particular, should save a considerable amount of time and money by utilising Landsat in their planning

This typical 'working' Landsat photo shows a MSS composite photograph. MSS images are normally used; the RBV system is a backup and is rarely needed. The picture was taken on 11 October 1972 and shows 13,000 square miles around Washington D.C. and Baltimore. The original from which this was printed is a 'false-colour' reconstruction in which the main land areas appear red, clear water black and silted water blue. For example, the light colour in the upper section of the Potomac River (the main tributary of Chesapeake Bay running upwards from the bottom left) is due to sediment that moved up from the coast during a storm from 4-7 October.

programmes. During June 1974, 34 scientists and technicians from 21 countries – including many of the emerging nations, Bangladesh, Pakistan etc. – attended a remote sensing seminar and training course at a USGS data centre where they were taught how to interpret and utilise remote sensing information from Landsat.

It is worth noting, before moving on to look at specific applications, that the coverage pattern of the satellites was altered with the launch of Landsat 2. Its orbit is 180° out of phase with that of Landsat 1, so the globe is now covered every 9 days rather than every 18. However, because of the limited capacity of the processing facilities (a maximum of 180 images/day) Landsat 1 is now generally restricted to intensive coverage of the US, regardless of cloud cover, with Landsat 2 concentrating on areas of prime interest in and out of the US.

Landsat information is coordinated with that from the Skylab EREP (Earth Resources Experiments Package), aircraft imagery and other sources in the USGS Earth Resources Observation Systems (EROS) programme.

Such a vast amount of knowledge has come out of Landsat that it is impossible to make a complete inventory in the space of this article. A number of the most interesting or significant discoveries are summarized below.

Minerals and Land Resources

Landsat images are providing the basis for the mapping of geological features on an unprecedented scale. Previously inaccesible areas are relinquishing their secrets to scientists and new structural features are coming to light in well explored regions. The Wind River area of Wyoming was mapped from prints of Landsat images and the number of known geologic structures multiplied by a factor of ten.

The San Andreas fault in California (which caused the disastrous San Francisco earthquake of 1906 and threatens to cause far worse devastation) has been intensively studied, but several new faults not previously identified were mapped from a Landsat 1 composite photograph, and this information could be invaluable in the effort to predict the forthcoming 'quakes and to reduce their effects.

William Fisher, of the USGS, in a paper presented in 1973 said: "The results of these investigations are relevant to three national problems – the need to accelerate the identification of minable minerals, the need to accelerate the finding and development of petroleum and the need to preserve the environment."

Scientists of the Eastern Oil Company found that images of the Anadarko Basin in Oklahoma revealed 76 anomalous features, 59 of which corresponded with producing oil and

This mosaic of cloud-free images of the U.S. was assembled by the Soil Conservation Service's Cartographic Division. It was originally made from 595 MSS images taken in the red band and produced at a size of 10 x 16 feet. Lithographic copies, 29 x 41 in., are sold to the public for $1.25. A similar mosaic has been made using green light MSS images.

USGS/NASA

gas fields, 11 were known but non-producing fields and the remaining 6 could not be correlated with known features. Of 35 "hazy" anomalies on the images, 33 correlated with producing fields or drilled structures. Additional work is continuing to find the extent to which this type of analysis can be used, but there is obvious potential for the use of Landsat in exploration for oil.

Environment

The pilot study in this discipline was made of Alaska, where the images are now considered indispensable. John Miller, who has worked on the project at the University of Alaska, explained: "One of the most crucial problems in Alaska today is a great environmental knowledge gap. This gap seriously impedes planning and adversely affects decision-making processes at a very critical time in the development of Alaska's economic and social regime.

"Alaska is so vast, and the Arctic environment so varied, that this environmental knowledge gap will not be bridged quickly by conventional means, or with normal dollar resources. This is why the ERTS programme, which has demonstrated its capability for economical, large-scale surveys, affords a unique opportunity to narrow the knowledge gap. The applications of ERTS data are playing a vital and timely role in the planning for the imminent and, we hope, orderly development of Alaska."

Major accomplishments have been reported in water quality investigations. Techniques have been established permitting semiquantitive estimates to be made of suspended solids in quantities from 5 to 1000 milligrams/litre, and of chlorophyll content. Large scale dumpings and sources of pollutant are easily seen, and illegal dumping has been detected in this way.

A number of investigators have used imagery to measure features affecting wildlife habitats, such as vegetation and water, that have indirect or direct impacts on population. In the past, mappings of this type have been extremely generalised and poorly defined due to the difficulty of access to remote or hostile terrain, but Landsat maps can view these areas and show up to 10 well defined vegetation classes compared with two to four shown by conventional maps; which, with surface water distribution added, gives a good map of the habitat.

Land Use

In this area of investigation, as with many others, Landsat

The Juneau, Alaska area is shown in this monochrome copy of a colour composite image. Healthy crops, trees and other vegetation show in varying shades of orange and red. Sparsely vegetated areas appear light pink and barren areas grey. Built-up areas are darker grey, and clear water various shades of blue.

NASA

This MSS image shows sediment plumes from coastal glaciers of Alaska. USGS EROS scientists using this and other images were able to map the extent of these 30-mile long plumes for the first-time.

USGS/NASA

appears to be cost effective. Surveying a state the size of Illinois using medium-altitude aircraft would cost about $1 million, by high-altitude aircraft $200,000 and by Landsat $80,000. Also, the satellite system is easier to coordinate and much quicker to use – a complete map of Rhode Island was produced in 8 days.

An experimental 1:250,000 scale photo image map has demonstrated that National Map Accuracy Standards could be obtained using Landsat images.

Land use inventory information from Landsat is being used by the states of Michigan, Minnesota, New York and Wisconsin to update their information management systems. In Wisconsin particularly it was found that the imagery was able to provide a more rapid and accurate supply of data than were existing sources.

Antarctica, a continent very poorly mapped, is becoming better known as a result of Landsat surveys.

Water Resources

For the first time it is possible to make a reliable estimate of the area of the Earth covered by water, with the satellites making repeated infrared observations of very large areas of the globe. The strong contrast in this spectral region between surface water and its surroundings makes it one of the most easily delinated features, and its area can be calculated with good accuracies.

Floods are monitored using Landsat images and can be of immediate help to relief organisations and governments who have to deal with the subsequent rehabilitation and clear-up – most notably Bangladesh. In April 1973 the Mississippi flooded some 300,000 acres of land near St. Louis in the worst disaster of its kind on record for that region. Cooper Creek, in February 1974, poured out of its banks and flooded an area of the Australian outback 40 miles wide and some 140 miles long. Both of these were studied by the USGS EROS scientists who watched the growth and eventual recession of the waters and were able to see the "puddles" and damp areas left behind.

Almost 80% of the fresh water of our planet is locked in glaciers and icecaps, and the near infrared sensors of the spacecraft are providing valuable information here also.

Marine Resources, Oceanography

The synoptic view Landsat offers of the sea, and of coastal waters in particular, makes it ideal for studying large-scale circulation patterns using sediment as a natural 'tracer', easily visible in the images. Circulation patterns and sand transport have been examined using the pictures for the coasts of California and Alaska, where unexpected flows were revealed in the northern part of Cook Inlet. This type of information is extremely useful for predicting the dispersal of sewage and industrial effluent dumped near the coast; for harbour planning and dredging operations; and for selecting safe recreational sites or locations for inshore oil rigs and the like. Delaware, for example, is using Landsat in planning the emplacement of equipment for controlling and reducing oil spillage.

Sea ice – a hazard to shipping – can be monitored with ease from the orbital vantage point of Landsat and the feasibility of using multispectral photography to identify ice types, distribution and movement has been demonstrated. Canada is using imagery on an operational basis to route ships through ice-bearing water, in particular the North-West Passage, and has increased significantly the fraction of the year when ships can navigate through the arctic regions.

An analytical technique for measuring absolute water depth has been developed. Initial evaluation shows it is mainly useful for coastal waters up to 9 m in depth of low turbidity.

Colour enhancement by computer can show subtle brightness variations in the sea. For example, a Landsat image of the Mississippi Sound was taken simultaneously with the low pass of an aircraft seeking shoals of menhaden fish. Subsequent analysis indicated that the schools were found in, or closely adjacent to, water that registered as yellow in the processed Landsat photo. More research needs to be done, but again the potential is there.

Agriculture, Forestry, Range Resources

One scientist working in this field said "repetitive coverage.... it's critical – we can't live without it!" Certainly, the perspective of the Landsat images is opening great new possibilities, and can be of considerable value.

For example, a 530,000 acre area was inventoried using Landsat images. Some 8,000 fields were covered in three weeks, requiring 40 man-hours and resulting in maps with an accuracy of about 90%. This process is again economical – 800,000 acres of cotton-producing land have to be surveyed annually at critical times to control pink bollworm infestations, requiring 128 man-hours before Landsat. Now this can be done in 18 man-hours, a 9:1 improvement. The efficiency of the sampling can be shown by another example. A Landsat 1 image of the San Joaquin county in California was used to find 17 classes of crop, producing a more detailed and up-to-date map than was available, in 30 minutes. Crop area estimates are much more time-consuming but a 99% accurate estimate of the wheat area in Kansas was made, and the investigator reported unexpected successes. Accurate acreage estimation is vital when production predictions are to be made.

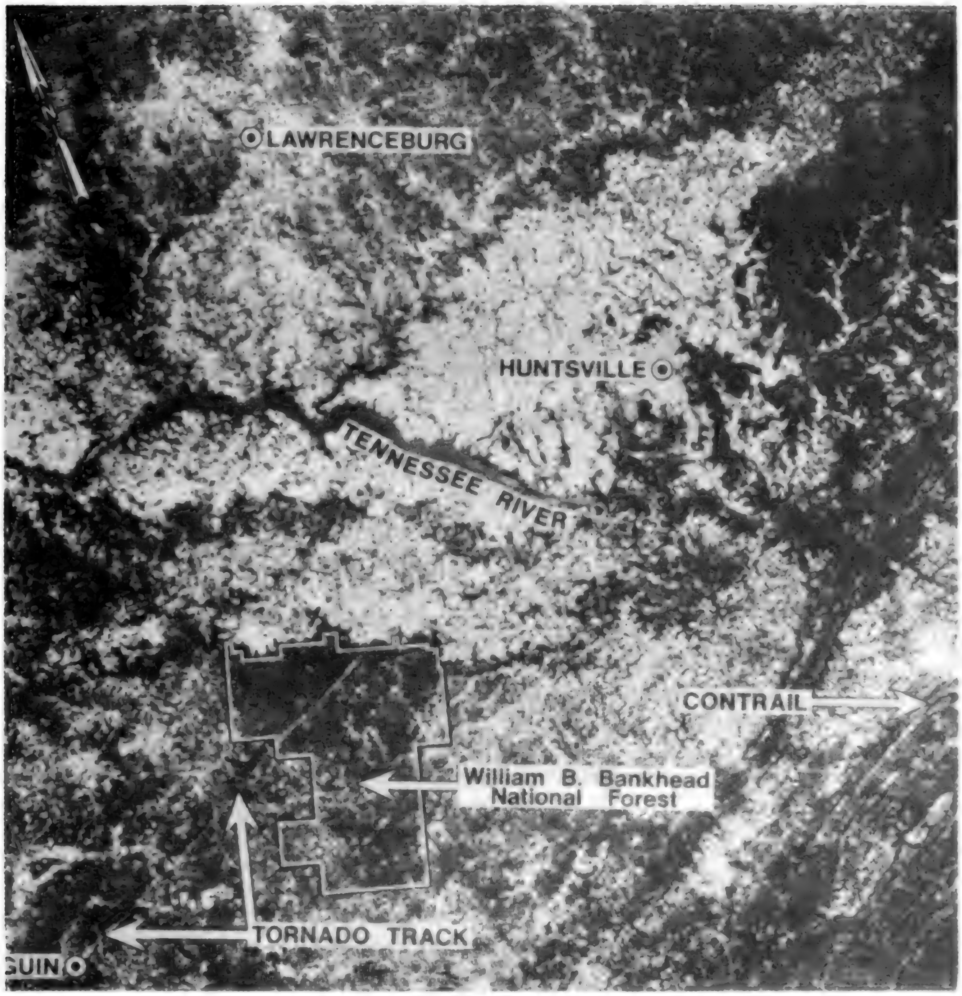
NASA has reported that Landsat "has made a significant contribution toward future relief of the drought and famine-stricken Sahel region of Africa." Features were discovered that demonstrated that controlled grazing could make it possible for some of the desert areas of the affected nations to be reclaimed and put to productive use.

At one tenth the usual cost timber volume is speedily calculated on the basis of multispectral photographs from the satellites. Volumes of timber cleared, amounts destroyed by forest fire and a number of other parameters can now be more accurately determined.

Cartography

The applications of Landsat to mapping have already been discussed in connection with other disciplines, but it is a field in itself, again with much potential. The quality of the MSS images permits useful, accurate maps to be constructed with scales of up to 1:250,000. One map in particular has created a lot of interest – the cloud-free mosaic of the US (excluding Alaska and other separated areas) put together by the USGS and now available to the public.

The simplest way to make a map from the Landsat images is simply to overlay the relevant information on to a print, and this is a frequent method. Computers can analyse the tapes to bring out a desired feature and print out a map directly. With careful correction of distortion based on ground controls, small areas can be mapped to larger scales than 1:250,000 – another factor which exceeds the expectations of the system.



On 3 April 1974 a tornado levelled the town of Quin, Alaska and cut a swath through adjacent wooded areas, uprooting trees over a path 2,000 feet wide and damaging others up to a width of nearly 4,000 feet. The track of the tornado was discovered accidentally by two USGS scientists who at first mistook it for an aeroplane contrail, but when they could not find a shadow and it showed up in succeeding images, correctly identified it. They said it showed the potential of Landsat for tornado damage assessment and relief aid.

USGS/NASA

The Richat structure in Mauritania, Northwest Africa, is the circular feature showing in this MSS composite image taken on 3 November 1972. It is thought to be an eroded sedimentary uplifted structure. Lava flow can also be seen.

NASA

Applications of Multispectral Photography

This table lists the main applications of each Landsat MSS spectral band, with the Skylab EREP S190 camera for comparison.

Application	Landsat Band (μm)	Applcns.	Skylab Band (μm)	Applcns.
1. Chemical composition of rocks, solar reflectance, soil types.	0.50 to 0.60	(2) (3)	0.41 to 0.46	(1)
	0.60 to 0.70	(2) (3) (4)	0.46 to 0.51	(2)
2. Vegetation signatures, multispectral reflectance.	0.70 to 0.80	(4)	0.52 to 0.56	(2) (3)
	0.80 to 1.10	(4) (5)	0.56 to 0.61	(2) (3)
3. Topographic mapping and photo interpretation.	10.40 to 12.60	(6)	0.62 to 0.67	(2) (3) (4)
			0.68 to 0.76	(4)
4. Vegetation: types and vigour, false colour interpretation.			0.78 to 0.88	(4) (5)
			0.98 to 1.08	(4) (5)
5. Terrain roughness, monochromatic reflectance, surface water distribution.			10.20 to 12.50	(6)
6. Rock and soil types, soil moisture boundaries, water sources, thermal emission, vegetation health, ocean temperature.				

The sensor for the last Landsat band, in the infrared centred on 11.50 μm, has yet to be flown. Only the S190 bands 1 to 8 and 13 are shown.

Landsat follow-on Investigations

In the follow-on programme for the satellites the main results of primary investigations have led to greater emphasis being placed on dynamic features and predictions in 109 investigations, briefly summarised below.

Agriculture: Several studies are being made of particular countries, frequently the less developed; one particular effort will be made to pilot an information system for all of Central America. Crop identification and acreage estimates are prominent, and temporal changes (such as the "green wave" effect) will be closely watched to improve prediction techniques.

Land use: Again, developing countries will be major study regions, with emphasis on broad, large-area investigations covering entire states or nations. Cartographic applications will be widely sought, exploiting procedures for aerial photography.

Geology: The search for mineral resources is considered of prime importance; the Yemen Arab Republic will be studied, typical of many poorer countries. Earthquakes and volcanoes will be further investigated with the DCP sensors.

Water resources: A wide variety of investigations are planned, covering both the more advanced and the emerging nations. Operational techniques will be developed to inventory and monitor water resources, and local agencies familiarised in the use of satellite imagery.

Marine resources: Here studies will mainly be concerned with US coastal waters although some investigation will be made into ice around Spitsbergen and Greenland, attempting to forecast its movement. Some ecological studies will be made – of phytoplankton, for example.

Meteorology: The DCP stations will again be used in this discipline, somewhat neglected in the primary investigations. In England, imagery will be used by Eric Barrett of the University of Bristol to make mesoscale assessments of cloud and rainfall. Data will be coordinated with those from other satellites, and rainfall predictions will be attempted.

Environment: Mining and other changing features will be the most important concern of the environmental follow-ons. Water quality and atmospheric aerosol content will also be monitored, Japan being one of the main study areas.

Interpretation techniques: Algorithms will be used to increase the precision, flexibility and efficiency of Landsat interpretation techniques. Improvements will be made in the corrections to imagery for atmospheric distortion, sensor location errors, decay functions and other viewing factors.

Conclusion

It seems appropriate to end this survey as it began – with a quote from NASA administrator James Fletcher, this time from his address to the national AIAA meeting in February this year. "NASA's programmes are now oriented directly towards today's needs and problems," he said. "We have turned from the beginning of space flight where we were occupied with learning to operate in space to a period where we are learning to use space for man's benefit directly.... Management's task is to structure its picking and choosing process so that the probability of selecting the 'right' technology is maximised." Landsat seems to have been one of the "right" technologies, and one hopes that its many accomplishments will lead to more advanced satellites of its kind, and that they will contribute to the better world we seek.

Acknowledgement

Many individuals and organisations too numerous to mention have assisted with this paper, but the author would like to extend his special thanks to the following: The National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration, the US Geological Survey, the General Electric Company of the USA and the Aerospace Industries Association.

SCOTT HEADS FLIGHT RESEARCH

David Scott, the former astronaut, has been appointed director of NASA's Edwards Flight Research Center. Scott, formerly deputy director of the Center, replaces Lee Scherer who has become director of the John F. Kennedy Space Center.

SOLAR SYSTEMS AND LIFE

By Ian Ridpath*

With new efforts being made to soft-land robot equipment on the planet Mars, we re-open our enquiry into the origin of life in the Universe. This article deals with theories of the origin of solar systems and the chemical 'building blocks' which seem to prepare the stage for biological evolution.

Introduction

One factor that vitally affects our chances of finding extraterrestrial life is the number of Solar Systems like our own that may exist in space. The earliest scientific ideas about the origin of the Solar System, due to the German philosopher Immanuel Kant and the French mathematician the Marquis de Laplace, visualized stars and planets being born together as a natural outcome of the contraction of spinning clouds of gas in space.

Then, earlier this century, the more catastrophic theories of near-collisions between two stars, with a filament of gas being drawn out to form the planets, gained ground. Yet, as physicists showed, incandescent gas would rapidly disperse into space, rather than collect into planets; for this and other reasons the theory was untenable. From the abandonment of the collision hypothesis came the realization that the Solar System must have formed cold.

Astronomers have now returned to the idea that the formation of planetary systems is intimately bound up with the birth of stars. This article is an attempt to review the processes involved, as currently understood. The conclusion is that most stars which are not members of double or multiple systems are likely to have planets. If each solar system has about as many planets as our own, then planets may actually be more numerous in the Galaxy than are stars.

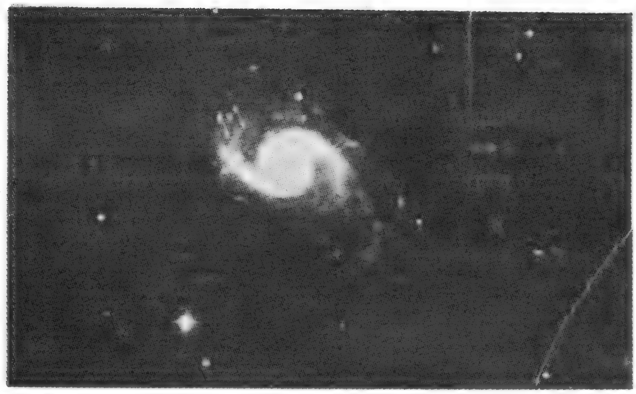
From Gas to Globules

A star begins, most astronomers agree, as a widespread cloud of dust and gas in the spiral arms of our Galaxy. The material of which it is made is the primordial mix of hydrogen and helium gas, seasoned with heavier elements disgorged from aged stars in supernova explosions.

Yet such a cloud on its own will not inevitably form into stars. We see many such clouds in the Galaxy which are apparently quite happy the way they are. They show no signs of making stars. To form into a star, something must nudge the cloud so that it starts to collapse in upon itself. Then its own gravity will pull it together.

Astronomers have suggested several ways that such a collapse may be started off. They think that big swirls could be set up in the cloud by magnetic fields in the Galaxy, or by heating from cosmic rays or X-rays. According to one now-popular theory, there is a constant wave of gravitational force that sweeps round the Galaxy, which is responsible for setting up the spiral arms. As this wave sweeps through gas clouds, it causes the material in them to bunch up. Where the clouds become dense enough, they will start to collapse into tiny opaque spheres.

Yet, however star formation starts off, the theorists calculate that such a collapsing cloud must have a mass at least 1,000 times that of the Sun. In other words, stars never form on their own. They must come into being as a complete field. Astronomers point to the Coal Sack nebula in the southern hemisphere as an example of just such a process in operation. Smaller, darker blobs can be seen within the Coal Sack's sooty spread. It seems that a star cluster is about to



The bright spiral galaxy NGC 1566. This spectacular object has an even more spectacular nucleus: explosive processes, which astronomers do not yet fully understand, are liberating enormous amounts of energy. We can observe violent chaotic motions with velocities of 2000 km/sec. in this central nucleus.

be born there.

Before such a cloud starts to collapse, it has a temperature of between about 20 and 60 degrees above absolute zero. Even at this temperature the cloud is quite warm in comparison with empty space, because it is being heated by cosmic rays and X-rays. But, as parts of the cloud get denser, these heating agents are shielded out and the cloud's temperature actually falls – this time to about 10°K.

This is not the popular picture of a forming star, but the work of radio astronomers supports the theorists. Those complex organic molecules observed in the interstellar clouds tell that the temperatures and the densities are exactly as predicted. Indeed, even until the moment that the star first switches on, the temperature in the cloud around it rises to no more than a few hundred degrees.

At several places inside the low-temperature cloud the density becomes high enough for Sun-sized masses of dust and gas to collapse. The cloud fragments into the individual condensations that directly spawn stars. Throughout the Galaxy, astronomers can see small, dense clouds that are collapsing on themselves at a rate of about 1 km/sec – just the rate that is expected for a forming star.

A single star on its way to becoming a recognizable, glowing object is thought to look like the tiny dark globules that were discovered by Bart Bok, and named after him. Such Bok globules seem to be about the same mass as our Sun, and to occupy an area not many times larger than our Solar System.

Such a globule will probably be slowly rotating. There is no way to get rid of this rotation, so it remains trapped in the collapsing globule. As the globule compresses itself, the rotation is compressed too. If it is big enough, the globule may end up spinning so quickly that it bursts like a flywheel, flinging matter out into space. Among this matter may be

* *Ian Ridpath, a science journalist and amateur astronomer, is the former editor of the popular astronomy magazine "Hermes." This article is adapted from his book "Worlds Beyond: A report on the search for life in space," published this summer by Wildwood House.*

other condensations that later turn into individual stars.

About half the stars in the sky are double or multiple, and this is one way of explaining their frequency. But another point of view suggests that multiple stars can be formed from the left-overs after a single star is born.

From Globules to Stars

At the globule's centre, the density of the collapsing matter goes up most rapidly. Most of the mass remains left behind, forming a dusty envelope that collapses much more slowly – a reluctant follower of the downrushing core. As the overall density of the globule increases, and the dust and gas particles rub together, the globule can no longer radiate away all the frictional heat. At last it begins to warm up; it has become a protostar.

Astronomers can detect the heat of such forming stars at infra-red wavelengths. They believe that there are a number of embryo stars in part of the Orion Nebula, which glows to the naked eye as a result of the stars that have already formed within it.

As the material of the surrounding globule cascades down upon the surface of the protostar, its temperature quickly rises to many thousands of degrees, and it glows more brightly than our Sun does today. Although a globule may take a million years to first form, once it has begun to contract it may take a few more years before the protostar is first seen to glow. The energy of its gravity then powers it for around 10 million years. This energy is eventually replaced by the steadier glow of the nuclear fires that are tindered by the extreme temperature and pressure at the young star's heart.

Possible evidence for the early stages in a star's life came in 1954 when astronomers photographed a glowing clump of gas in Orion that had not been visible on pictures of the region taken a few years before. They interpret this as the observation of a new star that has just been switched on by its gravitational energy. Such ideas will be confirmed if similar protostars appear at the infra-red sites in Orion that are believed to be collapsing globules.

Another class of objects, called T Tauri stars after the first one of its type to be discovered, seem to be young stars still embedded in the swirling, cloudy envelope that gave birth to them. Astronomers believe that these objects are the visible link between dark globules and full-formed stars.

And they are important because they seem to be shedding material as the Sun is believed to have done in its early days – a remarkable confirmation of the visionary work of the Marquis de Laplace. As Laplace foresaw, a shrinking star is likely to be rotating so swiftly that the gas at its surface reaches escape velocity. A stream of proto-sun material spirals away into the surrounding cloud, and flattens out into a spinning disk around the youthful star. Here is the assembly yard for a future planetary system. The realization that planets are a natural by-product of the formation of stars has boosted the optimism of many scientists that we are not unique.

In the 5 July 1974 issue of *Nature* the Soviet scientist Eduard Drobyshevski added an interesting twist to this tale. He contends that the outer regions of a forming protostar would be so unstable that almost all of its material will be thrown into a ring. On this theory, the planet Jupiter would be the original core of the dismembered protostar, and the Sun would form from the material that it threw off.

According to Drobyshevski, the small planets between the Sun and Jupiter were formed as matter streamed between the two components, and the outer planets were formed from the remaining gas that was spun off from the ring. In any case, either a double star or a planetary system is the natural by-product of this process. Drobyshevski's theory is still too new to have received critical discussion from other astronomers.

The Chinese-born astrophysicist Su-Shu Huang of Northwestern University, Illinois, believes that in such events as the switching-on stars in Orion we are observing the first stages in the birth of planetary systems. As the newly glowing stars eject matter into a ring around them, the remains of the surrounding gas envelope collapses into a disk as a result of its high-speed rotation.

The next stage remains the most disputed among theorists. Almost certainly, they now believe, the material inside the star produces a magnetic field that snakes out into space. And a 'wind' of atomic particles, blown off the incandescent surface of the energetic young star, curves outwards along these magnetic lines of force. The particles that gush outwards from the swiftly spinning star carry its rotation into

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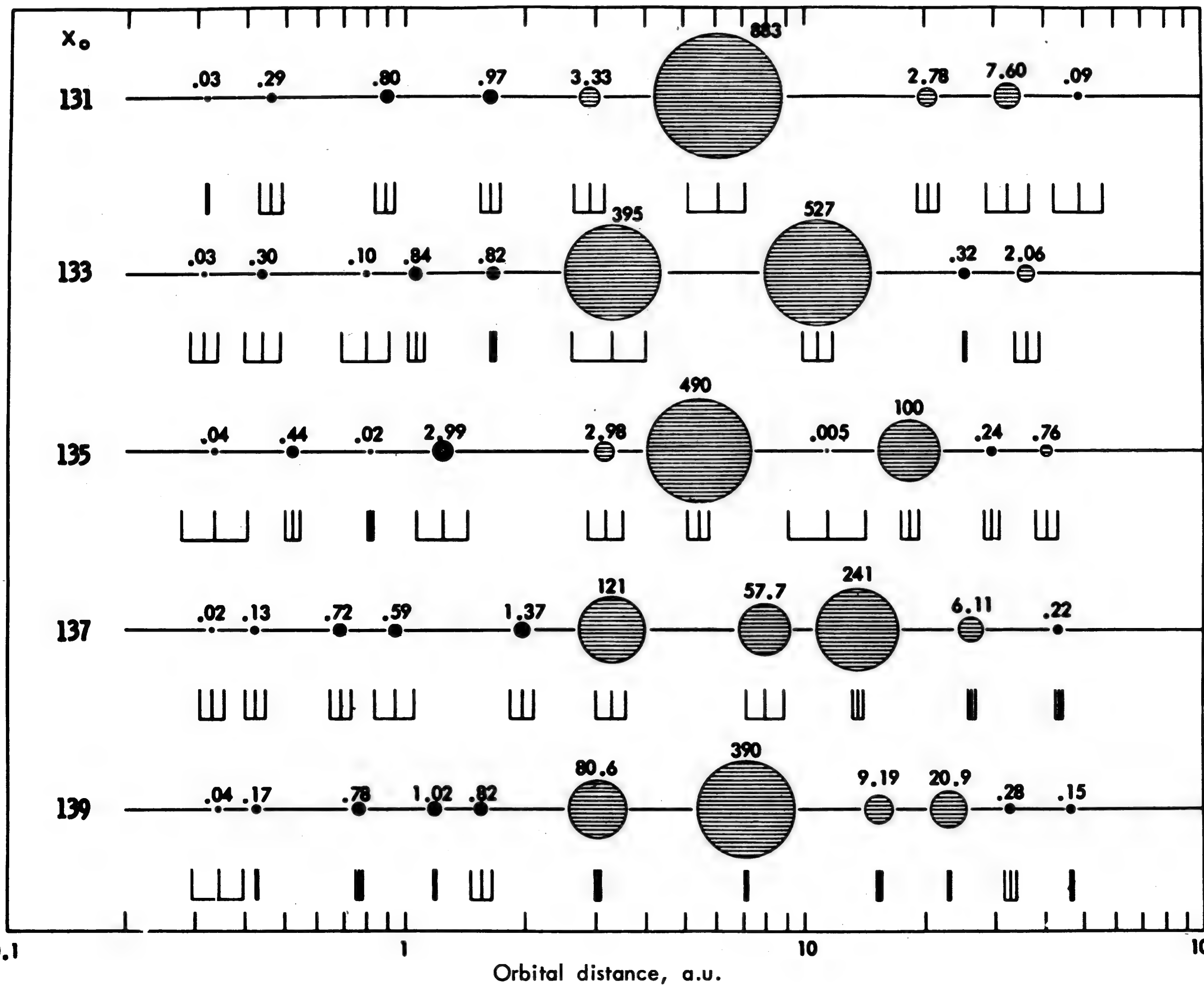
30 Doradus. This is a huge emission nebula in the Large Megellanic Cloud. The nebulosity comes mostly from hydrogen caused to shine by hot bright stars embedded in it; the mechanism is akin to the excitation of hydrogen in advertising signs. The loops are probably related to magnetic fields, and the whole region is one in which star formation is actively taking place.

Events that lead to the build-up of a planetary system from the solar nebula have been simulated on a computer by the American scientist Stephen Dole. He starts with a Sun-sized star surrounded by a disk of gas and dust similar to that which spawned the planets. Inside this cloud he imagines that the dust grains on their orbits round the Sun grow by random collisions until a suitable nucleus for a planet is built up. The computer works out what happens next.

Where two such planetary nuclei come close enough to be gravitationally attracted, or where their paths cross, they coalesce into one larger body. As these growing nuclei orbit within the cloud, they sweep out dust-free lanes. The largest objects so formed can also draw in gas. The process continues until all the dust is swept up and the left-over gas is driven out of the system by the solar wind.

Dole reported this work in *Icarus,* 13, 494 (1970). This diagram, hitherto unpublished, shows the results of a number of computer runs. The figures on the left indicate different density conditions in the nebula; the figures at the bottom are distances from the Sun in astronomical units; figures above the planets are masses in terms of the Earth's mass; brackets below the planets indicate the eccentricity of each orbit.

Despite varying the conditions slightly between each run, the planet-building process came up with small rocky planets closest to the Sun, large gas planets in the middle of the simulated solar system, and small planets again in the outer orbits. The lower example in this diagram has considerable similarities with our Solar System. A copy of Dole's computer program has been purchased by the Project Daedalus starship team to study the conditions they might expect to encounter in other solar systems.



the cloud. The effect is to brake the spin of the star, and to wind up the spin of the disk of dust and gas.

This helps explain one of the observed oddities of the Solar System: most of its mass is concentrated in the Sun, but most of the rotation is spread among the planets. Without some form of brake on its spin, the Sun would be expected to turn once every few hours, rather than once a month as is observed. Equally, the majority of the other single stars in the sky seem to spin far slower than would be expected if they had formed from a collapsing cloud of gas. Astronomers believe that these stars have also been disk-braked – which Huang considers is another pointer to the frequency of planetary systems in our Galaxy.

Calculations suggest that the obese early Sun would have begun to shed its spare-tyre material when it had condensed to about the size of the present orbit of Mercury. The transfer of rotation from the Sun would have spread this material into a disk extending throughout the present-day Solar System.

This disk of dust and gas is termed the solar nebula. Unlike the filament of gas that is drawn from the Sun in the collision hypothesis, this nebula would not be incandescently hot. The Sun's outer layers would still be relatively cool, so that the material spinning off into the disk would be no hotter than 1,000 degrees – and in many places much less.

From Solar Nebula to Planets

Theorists still argue about the exact events in planetary build-up. But the consensus of views is as follows. Inside the nebula, specks of dust collided and stuck together to make larger lumps. Each dust speck, like the grains in interstellar clouds, was a smoke-sized particle formed of many millions of the atoms that make rock and metal.

The process by which the dust motes stuck together is called cold welding, which scientists can simulate in the laboratory. The grains aggregated into larger lumps, perhaps a foot or two across, which formed a carpet through the plane of the Solar System. Each lump, on its own orbit round the Sun, would grow by collisions with other lumps until it was big enough for its gravity to attract other lumps. By this random process, meteorite-sized fragments and then asteroid-sized planetesimals would form. And the time-scale could be very short – these emerging planets would grow in a matter of a few thousand years, the theorists calculate.

In their earliest stages, then, the solid cores of the planets were subjected to a continual bombardment as the major masses of the Solar System were swept up. In some cases, large-sized lumps were captured into orbits around the young planets, where they remain as natural satellites. The largest planets of all – notably Jupiter and Saturn – were able to draw in their own mini-nebula of dust and gas, which developed by similar processes into a complex system of satellites, like a smaller version of the Solar System.

There were other events in the nebula that helped shape the final form of the planets. One of these was the effect of the solar wind, which blew much of the nebula away. The planets closest to the Sun were built up of the heaviest material, which was less easily pushed away from the Sun.

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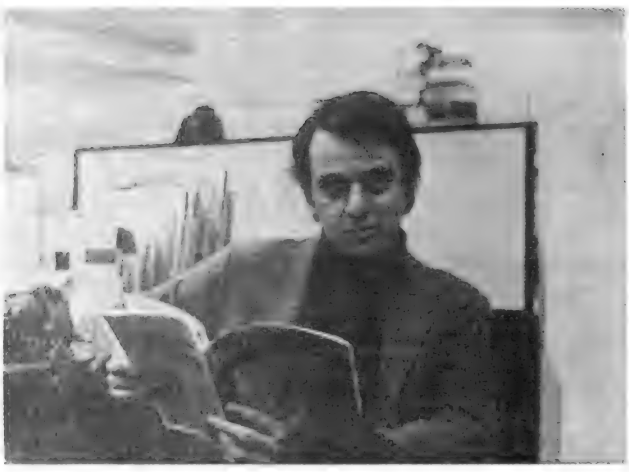

Professor Carl Sagan.

Extrasolar planetary systems, and their effect on the number of civilizations in the Galaxy, received their most extensive scientific discussion at the 1971 CETI conference held at Byurakan. Astrophysicist Tom Gold of Cornell University mentioned the type of stars we should survey for life: "We are interested in solar systems elsewhere that have a time-scale as long as ours, or of that order, in order that there may be enough time to evolve intelligent life," he said. "That immediately means that we are not interested in systems that might form around the very massive, very bright stars, since those stars have very short lifetimes; their later evolution would make any further life on their planets impossible. This consideration would restrict us to stars from those a little bit brighter, a little bit more massive than the Sun, down to stars very much cooler and very much less massive than the Sun."

Carl Sagan sought to use information on the origin of planets and the development of life to calculate the likely number of civilizations in our Galaxy at present. The number depends strongly on the average lifetime of civilizations; Sagan took the value of 10^7 years for the lifetime of a technical civilization. Summarizing the results of his calculation, he said: "There are a million technical civilizations in the Galaxy. This corresponds roughly to one out of every hundred thousand stars. Assuming these civilizations are distributed randomly, it follows that the distance to the nearest one is a few hundred light years. With any numbers like these the long-lived advanced civilizations dominate the picture utterly."

Sebastian von Hoerner of the National Radio Astronomy Observatory examined the possibility of using planets of other stars for population overspill – and came up with a surprisingly bleak result. "If we populate all habitable planets within a sphere of increasing radius, such that the volume of this sphere increase with 2 per cent per year (our present growth rate), then the limit is reached when the radius of the sphere increases with the speed of light," he said. "The resulting numbers are amazingly small: the limiting radius is only 50 parsec = 150 light years. Within this sphere are 30,000 habitable planets, but starting with 1 today, and increasing with 2 per cent per year, it takes only 500 years to populate all of them as densely as our Earth is now. After that, a growth rate of 2 per cent per year cannot be maintained without overcrowding, and we are back to the same problem."

In this cloud of gas, called the Lagoon Nebula, stars on the left have just formed, while the process of star birth seems to be continuing in the nebula to the right. *Hale Observatories*

These planets have a core of heavy metal sheathed by rock.

Most of the gas in the solar nebula was quickly pushed out into the depths of the Solar System, where it could be captured by the giant planets forming far from the Sun. But at the very edge of the Solar System, the gas would disperse before it could form into planets. As many as 99 atoms out of every 100 that spun off from the shrinking Sun were lost into space for ever. Mostly these were the lightest gases, hydrogen and helium.

The first atmosphere grabbed by the gravity of the Earth was made up from the traces of gas that had not been spun away from the Sun. Here was ammonia, methane, and water vapour, plus those more complex organic compounds that radio astronomers detect in the clouds around forming stars – a brew that chemists belive could have forged the first complex molecules of life. Astronomers are currently coming to regard the chain of events from the formation of a star to the origin of life as one continual evolutionary process.

In time, the heat of the warming Sun would have evaporated this primitive atmosphere of the Earth – a type of atmosphere which the other inner planets may also have possessed. But simultaneously the flaring volcanoes of our juvenile planet were exhaling the gases of our secondary atmosphere, including the water vapour that condensed into rain and filled the seas. Though they formed cold, the natural radioactivity of atoms inside them would have heated the planets to melting temperatures.

So here, supported by the work of astronomers and geologists, are all the conditions that biochemists believe that they need to explain the origin of life.

Further Reading

I have not tried to survey in any detail the numerous, and frequently conflicting, theories of the origin of the Solar System. An excellent review by Iwan Williams and A. W. Cremin will be found in the *Quarterly Journal of the Royal Astronomical Society*, 9, 40, (1968). Williams is also the author of a forthcoming book on the subject. Another exhaustive review is "Extrasolar Planetary Systems" by Su-Shu Huang in *Icarus*, 18, 339-376 (1973). For early events in the life of stars see "Collapsing Interstellar Clouds" by Richard Larson in *Annual Reviews of Astronomy and Astrophysics* for 1973. An excellent popular article dealing with the subject in some detail is "The Birth of Stars" by Bart J. Bok, *Scientific American*, August 1972.

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CETI FROM COPERNICUS

By A. T. Lawton

Introduction

Radio frequencies have long been considered the best means of communicating across interstellar distances, and current experiments are scanning nearby stars for signs of artificially generated signals. To date all the results have proved negative.

An almost equally historical alternative – the use of lasers – has been neglected for several years, but events have recently turned the tables, and with the aid of the Goddard Flight Centre's Orbiting Astronomical Observatory 'Copernicus', three solar class stars are currently being examined for laser type signals. This paper discusses the basis of the experiments, speculates on methods of generating the particular signals involved, and then goes on to suggest other candidates for the programme.

Use of Lasers for CETI

Historically, this was first proposed by Townes and Schwartz [1] who in 1960 suggested that lasers were a viable alternative to radio systems, and proposed searching the spectra of solar type stars. They suggested that the absorption lines of calcium at 0.3934 μ metres and 0.3968 μ metres (3934 Å and 3968 Å) at the violet end of the spectrum might be specially suited for such work, see Fig. 1. These proposals were not taken seriously, mainly because of the higher background radiation at optical wavelengths reducing the effective range over which signals could be transmitted.

These views are not shared by Herbert F. Wischnia, a consulting electro-optical engineer from Stamford Connecticutt who is a guest investigator in the 'Copernicus' programme and is now actively scanning the stars Epsilon Eridani, Tau Ceti, and Epsilon Indi for signs of laser emission [2]. Wischnia is particularly interested in ultra-violet wavelengths below 0.28 μ metres (2800 Å) and since these cannot be observed on Earth due to ozone layer atmospheric absorption, the work has to be done by satellite. The technical difficulties in detecting radio signals are related to knowing where and when to look for them, and at what frequency to listen. Ultra-violet laser search experiments avoid this problem according to Wischnia who asserts: "Lasers in the vacuum ultra-violet part of the optical spectrum represent an efficient and logical electromagnetic radiation source which could be used by an extra-terrestrial community to announce their presence to us. Ultra-violet laser beacons offer the potential of high power combined with high efficiency. Further, stars with a temperature near that of our own Sun radiate very little energy in the vacuum ultra-violet, so that the telescope receivers are not blinded by natural stellar radiation. These reasons make the ultra-violet lasers rational candidates for intergalactic beacons".

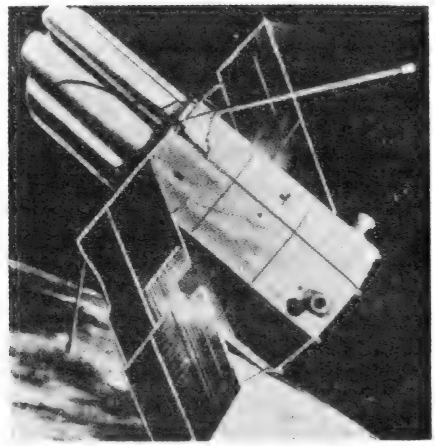
This basis for experimentation has received the blessing of the Goddard Space Flight Center and in November 1974, Wischnia scanned the first star – *Epsilon Eridani.* The 'Copernicus' telescope was trained on the target for 14 orbits while the spectrometer scanned the ultra-violet spectrum for potential laser signals to Earth. The data transmitted back from the satellite is now being analysed and present plans include scanning the other candidates *Tau Ceti* and *Epsilon Indi* during the summer and autumn of 1975. Again, the returned data will have to be computer analysed.

The Ultra-Violet Spectrum – Generation of Laser Signals

The proposed use of UV as a rational choice for CETI signalling may seem an 'oddball' for traditionalists. However, if examined in detail, there is much to recommend it. The UV spectrum is generally defined as extending from about 0.39 μ metres (3900 Å) down to about 0.030 μ metres (300 Å). Above these figures we are dealing with visible light, and below them we encounter 'soft' X-rays.

Of particular interest in this waveband are the Lyman series of absorption lines with wavelengths of 1214 Å, 1024 Å, 971 Å, 948 Å and 937 Å corresponding to the various fully excited states of the hydrogen atom. The predominant line in this series is the so called 'Lyman alpha' of 1214 Å, and it is quite possible that an extra-terrestrial civilisation may choose to generate a signal which may lie close to, or preferably right within the absorption band in exactly the same way as postulated for the K line of calcium depicted in Fig. 1. There will however be a significant difference in the laser generated line in as much as it will be 'coherent' and extremely narrow. The spectrometer in scanning across the appropriate sector would not necessarily be able to detect the coherent wavefront of the laser line – hence the need for further computer analysis to cross-correlate the results of successive scans. The effect of this correlation is to enhance the laser signal, since its in-phase components add up whilst the noise component of the natural emission/absorption tends to cancel. It should be emphasised that if an intelligent signal *is* present then the 'Copernicus' apparatus will *not* be able to decode it. To do this requires the addition of more sophisticated receiving and decoding gear (a local oscillator laser, and a suitable wide-band radio amplifier and detector system).

However, the reception of the laser carrier in itself would be a considerable achievement, and if successful, the appro-



Copernicus, launched in August 1972, orbits the Earth at a distance of about 450 miles (750 km) making possible precise astronomical observations of a number of celestial objects. The Princeton Experiment Package, in the central experiment tube, includes a 10 ft. (3.05 m) long UV telescope, a 32 in. (81.3 cm) mirror, and ultraviolet spectrometer and sensors for the telescope guidance system, able to view stars as faint as seventh magnitude. The Observatory is three-axis stabilised with a pointing accuracy of less than .1 second of arc. A major aim of the project is to investigate UV radiation emitted from so-called young hot stars in wavelength regions between 930 and 3,000 Angstroms.

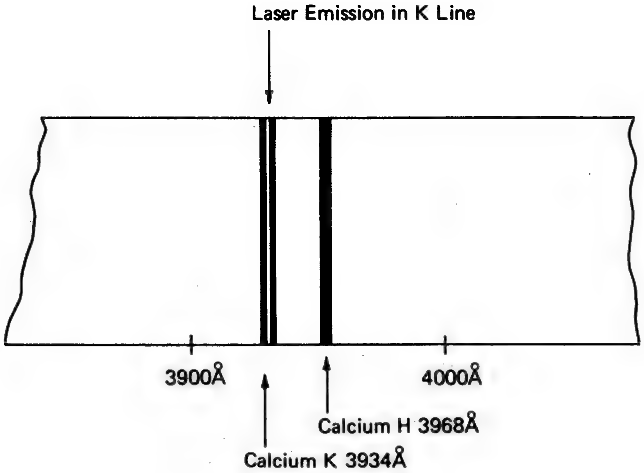


Fig. 1. Absorption line laser signalling.

priate gear would probably be made and launched with all possible haste. In fact such an experiment would be ideally suited to the Space Shuttle and Spacelab programmes of the 1980's.

Ultra-violet lasers are of comparatively recent origin and it is apparent from the work already carried out that certain excitation modes could be extremely efficient although results to date do not come anywhere near the theoretically expected figures.

Harvey [3] quotes work on semiconductor lasers where cathodes of zinc sulphide cooled to liquid air temperatures produced coherent UV light at 0.32 μ metres (3200 Å) when bombarded with a current of 30 m/a at a voltage of 15 Kv. In high powered developments of gas lasers peak powers of 2.5 Mw have been produced at UV wavelengths of 0.337 μ metres (3370 Å). However, in the above-cited cases the efficiences realised were the order of 0.1% although theoretically ideal efficiences of 40% are possible [4]. We have a long way to go and evidently Wischnia has faith in the ability of a super-civilisation to generate and control the intense energies required.

The background radiation of the Sun (and presumably similar stars) is down by a factor of 10^6 at Lyman α wavelengths when compared to the output in visible light [5] and such a reduction offers a considerable improvement in signal-to-noise ratio. The shorter wavelength also means a higher efficiency for a smaller mirror, providing it is sufficiently smooth. The 32 in. (81.3 cm) mirror on 'Copernicus' operating at the Lyman alpha wavelength in UV is directly comparable with a 150 in. mirror working in the yellow/green spectrum of visible light in terms of sensitivity and resolving power.

However, the disadvantages of using highly directional systems for CETI, which have been pointed out by Bates [6] and others, still apply to UV systems, and I personally believe that Wischnia may be unduly optimistic even though he does qualify matters by saying: "While it is possible to speculate on the success of detecting extra-terrestrial laser signals on the very first attempt, it is more realistic to plan for a systematic laser *and* radio search for the next 100 years." However, the experiments are being conducted as a "piggyback" rider to other items in a comprehensive programme, and only represent a very small percentage of the total usable time of 'Copernicus'.

Nevertheless, we still cannot be sure that any potential alien civilisation will have been transmitting to *us* at the particular times when the telescope is trained on the candidate star. Following the example set by Pace and Walker [7] I would suggest similar measures be applied to Wischnia's programme. We shall return to this possibility later.

Characteristics of Candidate Stars

Epsilon Eridani, Tau Ceti and *Epsilon Indi* are the nearest *single* solar type stars. Other stars may be closer, but they are either members of binary systems or are believed to have too low a luminosity to support life on any companion planets. The major characteristics of these candidates are shown in Table 1 where perhaps the most striking point is their reduced luminosity in comparison with the Sun and the odds against their possessing habitable planets let alone intelligent life. The term "habitable planet" means suitable to our way of life. The distance, star class, visual magnitude and luminosity figures were taken from [8,9], the figures for habitability from [10].

One point worth noting is that *Epsilon Eridani* has a possible cyclic movement in proper motion which may indicate that it has a companion. Tentative figures indicate a body of 6 times the mass of Jupiter orbiting with a period of 25 years [11]. It is stressed that these figures are highly provisional and almost certainly will be revised in the future. Figures are not yet available for perturbation of *Tau Ceti* or *Epsilon Indi* since they have a more southerly position than *Epsilon Eridani* and as a result present difficulties in obtaining accurate measurements.

Further Candidates for Examination

The stars listed in Table 1 have been selected because they present the best sample of Solar type stars in our immediate neighbourhood. If we go further afield and if we include binary systems, then the list of potential candidates is greatly extended. Provided that the percentage of time devoted to CETI searches, and the expected life of 'Copernicus' allows such an extension, then we can consider the stars listed in Table 2. By including binaries and multiple star systems in the search we have also introduced a time or epoch element in the search programme. Pace and Walker suggest examination of Solar type star binary systems at the times of periastron and apoastron (minimum and max-

Table 1. Characteristics of nearest solar type stars.

Name	Distance	Apparent Visual Magnitude	Spectral Class	Luminosity Sun = 1	Probability of Habitable Planet
Epsilon Eridani	10.8 L yrs.	3.8	dK2	0.25	1 in 30
Tau Ceti	11.8 L yrs.	3.6	dG4	0.36	1 in 28
Epsilon Indi	11.4 L yrs.	4.7	dK5	0.12	<1 in 50

Table 2. Characteristics of other possible nearby CETI candidates.

Name	Distance	Apparent Visual Magnitude	Spectral Class	Luminosity Sun = 1	Probability of Habitable Planet	Remarks
α Centauri A	4.3 L yrs.	0.0	dG0	1.0	1 in 19	'A' Component almost identical to our Sun;
α Centauri B	4.3 L yrs.	1.4	dK5	0.28	1 in 18	Small red dwarf companion may have planetary system.
70 Ophiuchi A	16.4 L yrs.	5.7	dK1	0.4	1 in 18	May possibly have a dark companion, but results believed spurious.
70 Ophiuchi B	16.4 L yrs.	7.4	dK5	0.083	<1 in 50	
η Cass A	18 L yrs.	3.5	dF9	0.98	1 in 18	Dark companion not proven. 'A' component is very similar to our Sun.
η Cass B	18 L yrs.	7.3	dK6	0.2	<1 in 50	
Σ Draconis	18.2 L yrs.	4.7	dG9	0.3	1 in 28	
36 Ophiuchi A	18.2 L yrs.	5.6	dK2	0.18	1 in 43	An interesting system; 3 "solar type" stars.
36 Ophiuchi B	18.2 L yrs.	5.4	dK1	0.18	1 in 50	
36 Ophiuchi C	18.2 L yrs.	7.5	dK6	0.08	<1 in 50	
HR 7703A	18.6 L yrs.	5.3	dK2	0.16	1 in 50	Small red dwarf companion.
δ Pavonis	19.2 L yrs.	3.7	dG7	0.35	1 in 18	
82 Eridani	20.9 L yrs.	4.3	dG5	0.38	1 in 18	
B Hydri	21.3 L yrs.	2.9	dG1	0.98	1 in 28	Very similar to our Sun.
HR 8832	21.4 L yrs.	5.7	dK3	0.25	<1 in 50	

imum separation distance between components). These times are unique to a particular system and can therefore be regarded as recognisable by other civilisations and (more important) predictable. If solar type binary systems lie within a distance of 300 light years, then 34 periastron – apoastron events will occur between 1975 and 1980. Pace and Walker quote from [12] which lists 536 systems with accurately known orbits. Of these 300 could have 1 or possibly 2 habitable planets about 1 or both stars and they conclude that the total number of habitable planets in this sample with precisely known orbits could exceed 500.

Pace and Walker considered only searching for radio signals, but I would suggest that time, money, and 'Copernicus' permitting, Wischnia should extend his programme as far as possible to match.

In summary, I would say that Wischnia's work has opened up new avenues of exploration in CETI work and although his initial phase may fail there are plenty of other sun-like stars to examine. It may possibly be argued that the 21 cm and similar 'radio lines' are *too easy* to use in CETI work, and that a civilisation should have a better overall knowledge of natural physics than the standards set by radio systems. In other words it is required to pass an *aptitude and an intelligence* test. We know that the technical standards required for UV interstellar laser transmission are much higher since operation above the home planet's atmosphere is essential. The generation and collimation of very high powers in coherent radiation at these wavelengths is to us at present a much more difficult task than the generation of radio CETI signals. We have already performed this task [13].

I sincerely hope that we succeed in this one. After all the original Copernicus revolutionised astronomy and completely changed Man's outlook on the Universe. Perhaps his electronic namesake will repeat the performance!

Acknowledgements

The author gratefully acknowledges the information given by NASA in Bulletin No. 75-130 May 1 1975.

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NASA EVA-1: THE FIRST OF 39

A retrospective look at major space achievements by David Baker

A DECADE ON – 6

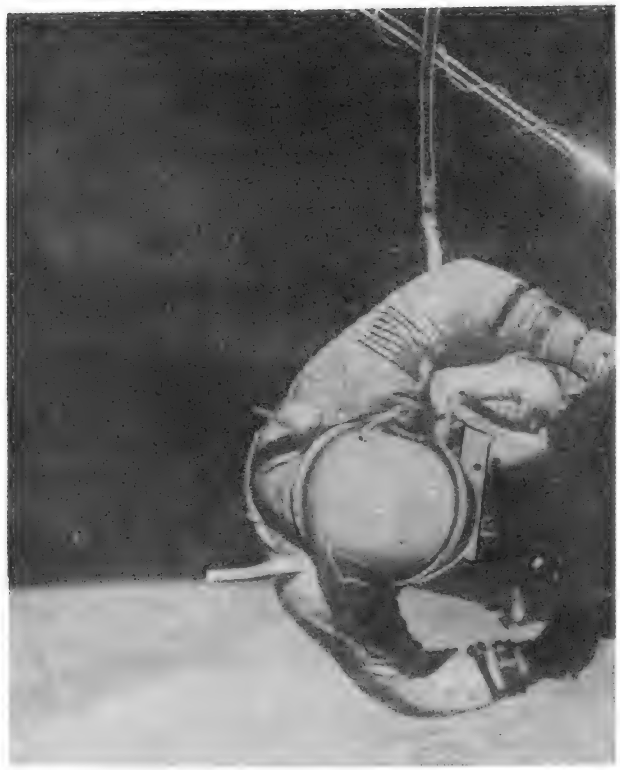
At precisely 3.16 p.m. GMT on 3 June 1965, two American astronauts lifted into space on NASA's sixth manned orbital mission. The spacecraft was Gemini 4 and the crew were James McDivitt and Edward White. It was the second time that a manned Gemini had risen from the Kennedy Space Center and it was to make history by adding a new phrase to space terminology: EVA, or Extra-Vehicular-Activity. Only one man had, at that time, experienced the magnificence of planet Earth from the loftiest vantage point of all. That man was Alexei Leonov who, on 16 March drifted at the end of a tether outside Voskhod 2. From the beginning, however, U.S. astronauts were denied the freedom of spectator pleasures. On the very first EVA mounted by NASA Ed White was set to a series of orientation evaluations that would, on later flights, lead to more ambitious work tasks until, in July 1969, two men would perform the ultimate splendour of EVA: the exploration of another world in space.

Plans for Gemini 4 envisaged a four-day flight in orbit, raising the U.S. duration record from the 34 hr. 20 min. of MA-9, a rendezvous with the spent second stage of Titan II and several in-flight experiments. Only 10 days before the flight did NASA decide to include an EVA operation in the schedule. Qualification of an emergency life support system, the all important tether and.a crude hand-held manoeuvring unit provided the unexpected opportunity for a space walk.

Following a postponement of more than an hour, due to a problem with the launch vehicle's erector, the flight finally got under way and Gemini 4 was put into orbit more than 100 miles above the Earth. At 7.42 p.m. GMT, only 4 hr. 26 min. after launch, the right-hand hatch was opened and Ed White slowly drifted up from his ejection seat. Moving slowly away from the hull of his spacecraft White tested his attitude stabilisation with the hand-held thruster unit, finding it useful for positioning himself. Fed with oxygen from the 25 ft. umbilical, which also supplied electrical power, communications and bio-medical telemetry, he cavorted in space and showed obvious signs of exhilaration at his new found freedom. Just 20 min. later it was all over and a reluctant astronaut returned to the cramped confines of his cabin.

In 1966 NASA again got an opportunity to practise EVA, with an ever watchful eye on the day when men would be walking on the Moon and setting up scientific research stations. Gemini 9-A gave Eugene Cernan an opportunity to spend more than 2 hr. outside his vehicle but efforts to try out a complex attitude manoeuvring unit were foiled due to exhaustion. The last three Gemini missions all demonstrated EVA, with two on 10 and 11 and three on 12. Each one of these flights also permitted a stand-up EVA, or SEVA, where the pilot was restrained from total exit. By the end of 1966, and completion of the Gemini programme, five U.S. astronauts had accomplished EVA totalling 12 hr. 25 min. Some nine exits had been achieved.

Then came Apollo and in March 1969, Russell Schweickart demonstrated the feasibility of executing an emergency transfer from the Lunar Module to the Command Module by means of EVA in a 38 min. exercise. Now, astronauts were using an autonomous back-pack of the type developed for lunar exploration. When next a man left his spacecraft there was nothing connecting him to the vehicle. The eleventh EVA came on Apollo 11 on 21 July (GMT), 1969. Man was on the Moon and Neil Armstrong was there with bootprints to prove it. Gemini EVA operations had been hampered by inadequate heat rejection capability from the air-cooled pressure suits. The Apollo EVA suit, known as the EMU (extra-vehicular mobility unit) on the Moon, used a liquid cooled system for removing body heat and this provided a far more flexible operating envelope for the crewman. Yet even this was taxed somewhat by the excessive energy of the second Apollo 14 surface traverse when Mitchell and Shepard tramped a mile uphill to a crater called Cone.



Ed. White (who subsequently died in the Apollo 1 fire) makes America's first EVA from an orbiting spacecraft on 3 June 1965.

National Aeronautics and Space Administration

Apollo 15 brought a modified suit and expanded life support capability to the science of EVA, permitting three periods of surface exploration of up to 7 hr. each. It also provided the crew with a vehicle for moving rapidly to designated sites enabling the geological examination of unique features, a speciality of the last three Moon missions. Also, the third member of the Apollo crew got a chance to stretch his space-legs when, *en route* back to Earth, he was required to perform a deep space EVA to retrieve film magazines from the Scientific Instrument Module in one segment of the Service Module.

In all, 20 EVA's were mounted by Project Apollo comprised of 14 lunar surface operations, 3 deep space film retrievals, 1 stand-up EVA from the upper hatch of the Apollo 15 Lunar Module, 1 Earth orbit EVA from the Lunar Module and 1 stand-up EVA from the Apollo 9 Command Module. To the 12.5 man-hr. of EVA accomplished within the Gemini Programme was now added 160.5 man-hr. from Apollo.

White floats free outside the orbiting Gemini 4. He wore a specially designed spacesuit and the helmet visor was gold-plated to protect him from the unfiltered rays of the Sun. It was a vital step towards landing men on the Moon.

Skylab

When the Skylab programme was planned it was expected to generate requirements for a total 29 man-hr. of EVA on 6 excursions from the Airlock Module during the three periods of manned flight. Early problems with the space station, however, necessitated repair operations to the solar cell 'wing', deployment of a sunshade and numerous minor tasks required for the continued operation of the facility. When the programme ended in February 1974 Skylab astronauts had performed 10 EVA's totalling nearly 82.5 man-hr. About 41 extra tasks had been assigned to EVA astronauts for the three flights.

It will be at least 4½ years before U.S. astronauts again exit a manned space vehicle, and then it will be from the Shuttle Orbiter above Earth. Gone are the days of hard lessons from Gemini, practical scientific work from Apollo and daring rescue operations from Skylab. That EVA's, when they are again written into flight plans, will now be routine maintenance and checkout activities is due in no small part to the pioneering efforts of Ed White during that day in June 1965.

Today, 10 years on, we recall the flight of Gemini 4 and remember the enthusiastic delight of a space-walking astronaut introducing NASA to a new activity for exploitation. From his efforts came 260.4 man-hr. of EVA in Gemini, Apollo and Skylab. Ed White moved on to the Apollo Programme and took his place alongside 'Gus' Grissom and Roger Chaffee to test Apollo 1 on 27 January 1967. Tragically, all three lost their lives in a flash fire that did much to develop the flight safety regulations of which NASA can be justifiably proud. His commander during the flight of Gemini 4 was James McDivitt who later flew with Scott and Schweickart in Apollo 9. He retired from flight status in June 1969, and became Lunar Landing Studies Manager, then Apollo Project Manager, before leaving NASA in September 1972 to enter industry.

MILESTONES

Continued from page 281]

space station. Mission objectives include studies of "the Sun, stars and planets and.... the Earth's surface and atmosphere." Vladimir Shatalov says mission also seeks ways of using both a single spaceship and a group of spaceships in near Earth orbit.

26 Soviet ground station directs laser beam at Soyuz 18/Salyut 4 to aid development of high-accuracy satellite tracking and distance measuring systems.

27 Three-day conference, "European Space Days", opens in Noordwijk, Netherlands, to promote ESA programme including Spacelab, Ariane launch vehicle, Marots maritime satellite, and five major scientific satellites.

27 Orbit of Soyuz 18/Salyut 4 is 344-356 km inclined at 51.6° to equator.

28 Soviets launch eight satellites (Cosmos 732-739) from one carrier rocket into orbits ranging from 1,475 to 1,532 km inclined at 74.0° to equator; period 115.8 min., probably for maintaining military communications network.

30 European Ministers and ambassadore of 10 ESRO member nations sign Convention in Paris formally setting up European Space Agency (ESA) which replaces European Space Research Organisation (ESRO) and European Launcher Development Organisation (ELDO) (see *Spaceflight* July 1975 pp. 252-254). Norway and Ireland announce intention to join ESA. Convention provides for meetings of ESA Council – the policy-making body – to be at Ministerial level, eliminating need for further meetings of Ministers within European Space Conference.

30 Soviets display replica of Salyut 3 space station and Soyuz ferry at 31st Salon International de Paris, Le Bourget.

June

1 *Tass* announces that between 3-30 June Soviet carrier rockets will be launched into target area of 130 n. miles radius in the Pacific Ocean centred 34° 49'N, 177° 14'W.

2 *Novosti* reports that second crew of Salyut 4 space station have already carried out a spectroscopic examination of the atmosphere and land surface of the European part of the USSR, Transcaucasia and Northern Kazakhstan.

2 Luna 22 in orbit around the Moon since June 1974 completes planned programme. By noon (Moscow time) craft had completed 3,296 lunar revolutions and 2,175 radio communications had been held with it. Additional research exercises are being conducted.

A CHRONOLOGY OF THE SPACE SHUTTLE – 4

By David Baker

Continued from August 1973 issue, page 319]

Despite the tight budget to which the U.S. aerospace industry is constrained, development of the NASA Space Shuttle continues to make solid progress. Below David Baker continues his diary of major events.

Shuttle spacebound.

North American Rockwell

1973

Apr. Development schedule modified due to FY1974 budget:

3rd Q 73 System Requirements Review.
1st Q 74 Orbiter Preliminary Design Review.
3rd Q 74 Programme Preliminary Design Review.
4th Q 74 First SSME integrated test.
1st Q 75 First SSME firing.
2nd Q 75 System Preliminary Design Review.
2nd Q 76 Orbiter 1 roll-out.
4th Q 76 First Horizontal Flight (Orbiter 1).
1st Q 77 System Critical Design Review.
4th Q 77 Orbiter 2 roll-out.
1st Q 78 Deliver first flight engines, ET and SRB.
3rd Q 78 First Manned Orbital Flight (Orbiter 2).

May 1 Chrysler Corporation are awarded a $1.9 million contract to document and distribute wind tunnel data for three years.

May 8 General Electric awarded a $234,788 contract for a 12-month study of future Shuttle Earth Resources applications.

May 31 NASA receives Shuttle External Tank RFP response from McDonnell-Douglas, Boeing, Martin-Marietta and Chrysler. Contract will specify procurement of 3 ground test tanks and 6 development flight tanks.

Jun. 22 Rockwell International, Space Division, receives $1.16 million contract for modification to NASA Industrial Plant at Downey, California, in preparation for Orbiter work.

Jun. 26 NASA JSC selects 21,000 lb. thrust Pratt & Whitney TF33-P-7 engine for Orbiter use during subsonic aerodynamic flight tests and ferry purposes. NASA plans to procure 25 engines.

Jun. 28 NASA MSFC extends Rocketdyne Shuttle Main Engine (SSME) contract by six months (to 29 February, 1976) adding $19 million to original $225.8 million. Option period extended by six months (to 31 December 1979) with a $1.04 million increase.

Jul. 16 NASA MSFC issues RFP for Solid Rocket Motor development. Technical proposals are due 27 August, cost proposals by 30 August. Companies requested: Aerojet, Lockheed, Thiokol, UTC. Total SRB weight will be 1.1 million lb., length 120 ft., diameter 12 ft., maximum thrust 2.5 million lb. First contract increment, for DD & T plus 6 development flights, ends September 79. Second increment, beginning early 78, requires production of 108 units (54 flights). Third increment, beginning July 1980, calls for 770 units (385 flights). New flight schedule establishes maximum (minimum) rates of 2 (2) in 1978, 11 (6) in 1979, 19 (10) in 1980, 28 (14) in 1981, 36 (18) in 1982, 51 (25) in 1983, 60 (30) in 1984, 1985, 1986, 1987 and 1988.

Jul. 25 United Aircraft, Hamilton Standard Division, are selected to design/produce Atmospheric Revitalisation Subsystem and Thermal Transport Loop of environmental control/life support system. ARS provides temperature, humidity, and carbon dioxide control for crew cabin and temperature control for cabin-mounted electronics equipment. THTL provides temperature control for hydraulic systems, fuel cells and cargo bay payloads.

Jul. Shuttle System Requirements Review re-sizes configuration. Orbiter has double-delta (81°/45°) 2,690 ft.^{2} wing 78 ft. in span with a total length of 122.8 ft. and a height of 56.6 ft. Orbiter weight dry is 150,000 lb. External Tank dry weight is 83,000 lb., propellent weight is 1.55 million lb., length is 155.4 ft. and diameter is 27 ft. Solid Rocket Boosters are each 145.1 ft. long, 11 ft. 10.3 in diameter, weighing 1.163

million lb. at ignition and 154,250 lb. at recovery. Total system is 181.25 ft. in length, with a GLOW of 4.204 million lb. to a 28° orbit and 4.165 million lb. to a 104° orbit.

Aug. 3 NASA MSFC receive proposals from Avco, Computer Services, Grumman, Systems Engineering and Wyle Laboratories for support services to be completed by mid-1975.

Aug. 16 NASA selects Martin-Marietta for design, development, test and evaluation of the External Tank at \$107 million to 1978. Tank assembly will take place at NASA Michoud Assembly Facility, New Orleans.

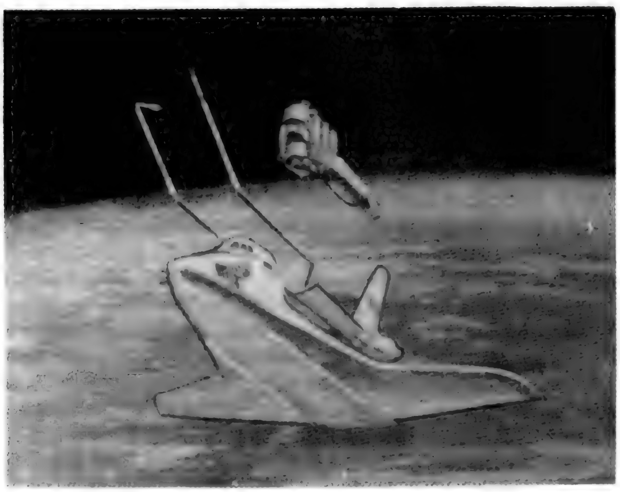
Aug. 31 NASA MSFC receives Solid Rocket Motor proposals from four bidders. See 16 July 1973. Booster integration contract is to be awarded in 1976.

Sep. 10 JSC reports near completion of a 17.5 ft. wide by 20 ft. long Orbiter Test Article, a simulated mid-fuselage section, to be used for internal stress distribution and heat transfer evaluation.

Sep. 24 NASA releases request for bids on Shuttle Training Aircraft to simulate subsonic flight characteristics.

Sep. 25 NASA JSC invites Lockheed to submit a proposal for wind tunnel tests using the C-5A as a ferry aircraft for the Orbiter. Work, to be completed by 14 December 1973, will evaluate the technical feasibility of the concept in 70 simulated runs during 40 hr. of wind tunnel time.

Oct. 3 MSFC selects Avco for facilities modification to Structures and Mechanics Lab' to be used for testing External Tank and Solid Rocket Booster.



Payload recovery.

North American Rockwell

Oct. 9 Orbiter length now 122 ft. All other dimensions as July 1973.

Oct. 12 Kearfott Division of Singer Company selected for \$10 million subcontract to Rockwell International for Orbiter inertial measurement unit.

Oct. 19 Rockwell International authorised by JSC to proceed with \$5 million modification of Orbiter assembly building at Palmdale, California.

Nov. 2 Pratt & Whitney Aircraft Division, United Aircraft, selected to design, develop and produce the fuel cells for the Orbiter under a \$10 million subcontract to Rockwell International. Each cell will produce 2-12 kW within 27.5-32.5 vdc range and water for drinking and subsystems cooling.

Nov. 20 NASA MSFC begins 1/12th scale SRB drop tests into Tennessee River from height of 200 ft. SRB model is 11 ft. long, weighs 105 lb. and carries three 11.5 ft. diameter parachutes. Tests will determine if parachutes can remain attached to full scale SRB during tow-back to KSC following splash-down.

Nov. 20 NASA selects Thiokol Chemical Corporation for DDT & E or Shuttle SRBs for \$106 million up to 1979. See 16 Jul. 1973.

Dec. 5 NASA MSFC awards \$160,000 contract to Norman Engineering for S-1C test stand modification for strength tests of Shuttle External Tank.

Dec. 13 NASA selects Grumman for \$19.5 million contract to modify two Gulfstream 11 aircraft for use as crew trainers for Shuttle Orbiter. Aircraft to be delivered by mid-76. See 24 September 1973.

1974

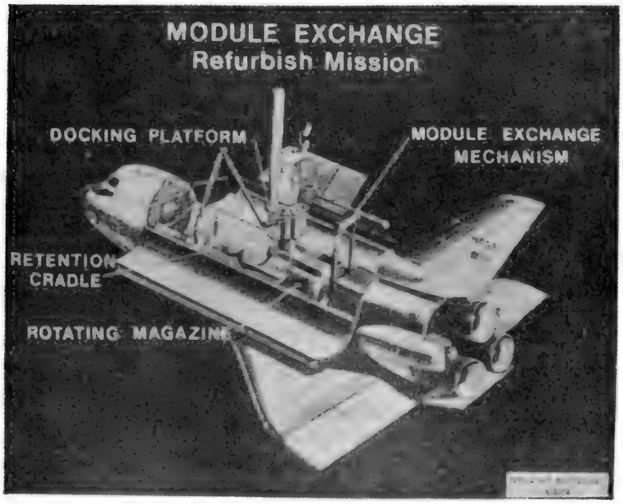
Jan. 28 NASA approves Fairchild design of Orbiter vertical tail, 27 ft. high and 22 ft. long at the base. First completed unit to be delivered to Rockwell International by May 1975.

Jan. NASA requests \$800 million for Shuttle work in FY1975.

Feb. 19 Singer Company Simulation Products Division receives follow-on contract from JSC for modification of Simulator Complex.

Feb. 25 NASA MSFC plans industry-assisted study of satellite-to-ground optical data link using Shuttle-mounted laser beams.

Feb Orbiter Preliminary Design Review re-sizes configuration. Orbiter has double-delta using 78 ft. wing span with a length of 122.3 ft. External Tank has dry weight of 78,000 lb. with propellent load of 1.55 million lb., a length of 153.9 ft. and a diameter of 27.5 ft. Solid Rocket



Payload refurbishment.

National Aeronautics and Space Administration

Boosters are 149 ft. long with a diameter of 12 ft. 2 in., weighing 1.266 million lb. each at ignition and 182,860 lb. at recovery. Thrust at sea level is 2.65 million lb. per SRB. Total system is now 184 ft. in length with a GLOW of 4.369 million lb.

Feb. Development schedule modified due to FY1975 budget:

3rd Q 74 Programme Preliminary Design Review.
2nd Q 75 First SSME integrated test.
2nd Q 75 System Preliminary Design Review.
3rd Q 75 First SSME firing.
3rd Q 76 Orbiter 1 roll-out.
1st Q 77 System Critical Design Review.
2nd Q 77 First Horizontal Flight (Orbiter 1).
1st Q 78 Orbiter 2 roll-out.
2nd Q 78 Deliver first flight engines & flight ET.
3rd Q 78 Deliver first flight SRB.
2nd Q 79 First Manned Orbital Flight (Orbiter 2).

Feb. NASA deletes the Pratt & Whitney jet engines for power-assisted subsonic aerodynamic trials (1977) and ferry purposes. Orbiter will be released from the mid-upper fuselage position of a Lockheed C-5A or Boeing 747 for aerodynamic trials.

Mar. 14 Singer Company, Kearfott Division, awarded subcontract for multiplexer interface adapters. About 200 units will be used on each Orbiter.

Mar. 25 Robert E. Lindstrom named Manager of MSFC Shuttle Projects Office, replacing Roy E. Godfrey who becomes special assistant to MSFC Director Dr. Rocco A. Petrone.

Apr. 3 NASA JSC signs $6.6 million contract with Charles Stark Draper Laboratory for development of Orbiter software.

Apr. 8 NASA selects McDonnell Douglas for $13.2 million contract for Shuttle Engineering & Operation Support.

Apr. 26 NASA selects Planning Research Corporation for design engineering support services for the Shuttle at Kennedy Space Centre and Vandenberg Air Force Base (launch site for polar missions).

May 17 IBM is selected by NASA JSC for two-year, $11 million, contract providing ground based computing and data processing system software design in support of Shuttle.

May 24 NASA JSC issues RFP to 21 firms for Orbiter simulator supporting Shuttle flight crew training. Proposals to be received by 10 July 1974. Orbiter Aeroflight Simulator will provide moving base trainer for astronauts.

Jun. 27 NASA Administrator announces decision to award Thiokol a contract covering Solid Rocket Booster development. Lockheed had contested 20 November 1973 award to Thiokol by protesting to General Accounting Office. GAO decided to permit NASA the final decision on 24 June.

Aug. 26 NASA MSFC begins a series of 24 acoustic test firings of 12 ft. Shuttle model (6.4%) using two 10,800 lb. thrust boosters and three liquid propellent engines producing 5,000 lb. thrust, making 60 acoustic measurements per simulated launch.

Aug. 28 Martin Marietta awarded a $26.5 million contract on 31 August 1978, for facilities preparation at Michoud Assembly Facility in support of External Tank manufacture.

Sep. MSFC near completion of a Shuttle Main Engine avionics test facility where math models simulate firings to evaluate hardware/software interface.

Oct. 18 NASA Administrator announces decision to use Flight Research Centre, Edwards, California, for first few orbital returns due to added safety margins and good weather conditions.

Dec. 20 NASA selects Singer Simulation Products for contract work ($8 million) for design, development and fabrication of an Orbiter Aeroflight Simulator. See 24 May 1974.

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The Editor is always pleased to receive items of correspondence, notes, comments or reviews for possible publication. Items submitted must be kept brief. The Editor reserves the right to shorten or adapt MSS to fill the space available.

GODDARD SPACE FLIGHT CENTER

By Mike Howard

Introduction

On 5 October, 1882 the man who was to become known as the "Father of American Rocketry" – Robert Hutchings Goddard – was born in Worcester, Massachusetts. During his lifetime Dr. Goddard worked towards his dream of using rocket propulsion for the conquest of space although at the time his work attracted little attention. It was not until several years after his death in 1946 that Goddard began to receive the recognition that he was due. Of the more than 200 patents resulting from his researches on liquid-propellent rocket motors, many are basic to the rocket engines of today.

The Facility

Situated in Greenbelt, Maryland, thirteen miles north east of Washington D.C., is the NASA facility that bears the name of the great rocket pioneer. The Goddard Space Flight Center (GSFC) was established on 1 May, 1959 as the first of the National Aeronautics and Space Administration's scientific laboratories devoted exclusively to space exploration. Goddard has a staff of over 4,000 people occupying its modern campus-like complex which is in an area that has become the centre for much of the United States' research and development. GSFC's scientific staff specialise in magnetic fields, energetic particles, ionospheres and radio physics, planetary atmospheres, meteorology, inter-planetary matter, solar physics and astronomy. The Center is responsible for the development and management of unmanned Earth-orbital satellite and sounding rocket projects, and control of the worldwide tracking and communications network for both manned and unmanned satellites.

Spacecraft

Many of the scientific experiments installed on U.S. spacecraft have been conceived, designed and/or built by scientists from Goddard while as NASA's project manager GSFC has been responsible for more than half of the Earth-orbital satellites launched by NASA.

Over the years Goddard has conducted many "cradle to grave" space science programmes made possible through its staff of highly qualified groups of scientists and engineers. Satellites that Goddard has been responsible for in this way include the Interplanetary Monitoring Platforms (IMP) designed to extend our knowledge of Sun, Earth, Moon relationships by conducting a continuing study of radiation in interplanetary space; and the Radio Astronomy Explorers (RAE) which made measurements of galactic and solar radio noise. Other satellite programmes managed by Goddard have included the Orbital Astronomical Observatory (OAO), Orbiting Geophysical Observatory (OGO), Orbiting Solar Observatory (OSO), the Earth Resources Technology Satellite (ERTS), and weather and communications satellites like Nimbus, ITOS, and Applications Technology Satellites (the latest of which, ATS-F, is the most complex, versatile, and powerful communications spacecraft ever developed).

Goddard has also been deeply involved with international programmes including Britain's Ariel, Canada's ISIS, Germany's AEROS, and Italy's San Marco.

Future Projects

Future Goddard projects include a joint NASA/ESA programme known as International Magnetosphere Explorer (IME), and the International Ultraviolet Explorer (IUE) which GSFC will develop in-house. IME spacecraft are scheduled for launch in late 1977 and mid-1978 to investigate solar-terrestrial relationships at the outermost the Earth's magnetosphere, to examine the structure of the near-Earth solar wind, and the shock wave forming the interface between the solar wind and Earth, and to continue the investigation of cosmic rays and solar flares in the interplanetary region near 1 AU. IUE is a 644 kg Explorer-class spacecraft due for launch in 1976 with the aim of obtaining high-resolution ultraviolet data on the spectra of many types and classes of astronomical objects.

Apart from its management of spacecraft programmes, GSFC also has responsibility for the Delta launch vehicle. Since their introduction in 1960 Delta boosters have launched more than 100 satellites with a success-to-launch ratio exceeding 90 per cent.

Tracking and Communications

To maintain an efficient tracking and communication system NASA has built three separate but mutually supporting worldwide networks of tracking stations.

The Space Tracking and Data Acquisition Network (STADAN), which is used for tracking unmanned scientific and applications satellites, has its control centre at the Goddard Space Flight Center. The Johnson Spacecraft Centre controls the Manned Space Flight Network (MSFN) which is responsible for tracking manned satellites such as Apollo and Skylab craft. Finally, the Deep Space Network (DSN) tracks lunar, planetary, and deep space probes, and is controlled by the Jet Propulsion Laboratory.

NASA links its networks using submarine cables, land lines, microwave links, and communications satellites under a system called NASCOM which in turn is part of a larger worldwide network known as the National Communications System (NCS). As the nerves of the human body converge on the brain so messages passing along the hundreds of thousands of miles of NASCOM's communications circuits meet at the main switching centre at Goddard from where they are re-directed to the appropriate control centres. Since it operates in a real time mode NASCOM can transmit data and voice communications anywhere in the world in a fraction of a second.

Goddard also houses the National Space Science Data Center which receives and stores much of the data collected by space science experiments to provide the basis for increasing man's understanding of basic physical phenomena.

Epilogue

During 15 years of operations the Goddard Space Flight Center has seen great progress in the field of space exploration and indeed, following the traditions of its namesake, has contributed greatly to that progress. Perhaps this extract from Dr. Robert H. Goddard's high school speech best sums up the tremendous advances in spaceflight since the professor began his experiments at the turn of the century: "It is difficult to say what is impossible, for the dream of yesterday is the hope of today and the reality of tomorrow".

Acknowledgement

The writer wishes to thank the staff of the Office of Public Affairs at the Goddard Space Flight Center for assistance in the preparation of this article.

Additional articles in this series include: Langley Research Center; Lyndon B. Johnson Space Center; Flight Research Center, and John F. Kennedy Space Center.

SATELLITE DIGEST — 85

A monthly listing of all known artificial satellites and spacecraft, compiled by Robert D. Christy. Information is based on that supplied by the Space Department of the Royal Aircraft Establishment, Farnborough and other sources. For information on the derivation of orbital parameters, abbreviations, etc., see July 1972 issue, p. 262.

Continued from July issue, p. 276]

Name, designation	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital Inclin-ation (deg)	Nodal period (min)	Launch centre, launch vehicle and payload/launch origin
Cosmos 707 1975-08A	1975 Feb 5.55 10 years	Cylinder + paddles	2 long? 1 dia?	503	547	74.03	95.14	Plesetsk USSR/USSR
Molniya-2M 1975-09A	1975 Feb 6.20 10¾ years	Cylinder-cone + 6 panels + 2 antennae 1250?	4.2 long? 1.6 dia?	634 602	40660 39745	62.78 62.81	736.86 717.59	Plesetsk USSR/USSR (1)
Starlette 1975-10A	1975 Feb 6.69 2000 years	Polyhedral spheroid 47	0.26 dia	806	1108	49.82	104.13	Kourou Diamant B France/France (2)
SMS 2 1975-11A	1975 Feb 6.92 indefinite	Cylinder 627 (fuelled) 243 (empty)	2.30 long 1.90 dia	35680	36685	1.10	1456.4	ETR Delta NASA/NASA (3)
Cosmos 708 1975-12A	1975 Feb 12.24 6000 years	Cylinder?		1369	1413	69.23	113.58	Plesetsk USSR/USSR
Cosmos 709 1975-13A	1975 Feb 12.61 12.7 days (R) 1975 Feb 25.3	Sphere-cylinder 4000?	5 long? 2 dia?	181 179	310 315	62.83 62.83	89.39 89.42	Plesetsk USSR/USSR (4)
1975-13F	1975 Feb 12.61 17 days 1975 Mar 1	Sphere?	2 dia?	179	269	62.82	88.96	Plesetsk USSR/USSR (5)
SRATS 1975-14A	1975 Feb 24.23 5 years	Octagonal cylinder 86	0.65 long 0.75 dia	249	3129	31.54	120.06	Uchinoura Mu 3C Japan/Japan (6)
Cosmos 710 1975-15A	1975 Feb 26.38 13.8 days (R) 1975 Mar 12.2	Sphere-cylinder 4000?	5 long? 2 dia?	176	335	64.99	89.61	Tyuratam-Baikonur USSR/USSR
Cosmos 711 1975-16A	1975 Feb 28.58 10000 years	Spheroid 40?	1.0 long? 0.8 dia?	1462	1496	74.00	115.53	Plesetsk USSR/USSR
Cosmos 712 1975-16B	1975 Feb 28.58 8000 years	Spheroid 40?	1.0 long? 0.8 dia?	1413	1492	74.00	114.95	Plesetsk USSR/USSR
Cosmos 713 1975-16C	1975 Feb 28.58 7000 years	Spheroid 40?	1.0 long? 0.8 dia?	1398	1490	74.00	114.75	Plesetsk USSR/USSR
Cosmos 714 1975-16D	1975 Feb 28.58 9000 years	Spheroid 40?	1.0 long? 0.8 dia?	1446	1494	74.00	115.33	Plesetsk USSR/USSR
Cosmos 715 1975-16E	1975 Feb 28.58 10000 years	Spheroid 40?	1.0 long? 0.8 dia?	1470	1508	74.00	115.75	Plesetsk USSR/USSR
Cosmos 716 1975-16F	1975 Feb 28.58 10000 years	Spheroid 40?	1.0 long? 0.8 dia?	1480	1517	74.00	115.96	Plesetsk USSR/USSR
Cosmos 717 1975-16G	1975 Feb 28.58 10000 years	Spheroid 40?	1.0 long? 0.8 dia?	1481	1538	74.00	116.21	Plesetsk USSR/USSR

Name, designation	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclin-ation (deg)	Nodal period (min)	Launch centre, launch vehicle and payload/launch origin
Cosmos 718 1975-16H	1975 Feb 28.58 9000 years	Spheroid 40?	1.0 long? 0.8 dia?	1430	1492	74.01	115.14	Plesetsk USSR/USSR

Supplementary notes:
(1) Orbital data at 1975 Feb 6.8 and 1975 Feb 23.3.
(2) Geodesic satellite carrying 60 flat laser reflectors for use in triangulation experiments.
(3) Second Synchronous Meteorological satellite. SMS 1 was launched 1974 May 17 (1974-33A).
(4) Orbital data at 1975 Feb 14.5 and 1974 Feb 22.1.
(5) Ejected from 1975-13A during 1975 Feb 24.
(6) Solar Radiation and Thermospheric Structure satellite, the third Japanese scientific satellite.

Amendments and decays:
1971-106A, Cosmos 462 decayed 1975 Apr 4, lifetime 1218 days.
1974-40A, Explorer 52 lifetime estimate is 3.7 years.
1974-58A, Cosmos 668 decayed 1975 Feb 21.28, lifetime 210.78 days.
1974-85A, decayed 1975 Mar 19, lifetime 141 days.

BOOK REVIEWS

The Pocket Encyclopaedia of Spaceflight in Colour: Missiles and Rockets
By Kenneth Gatland, Blandford Press, 1975, pp. 256, £2.40.

It is slightly unfortunate that the publishers have entitled this an 'encyclopaedia', implying an alphabetical assembly of short essays, for in fact this is a straightforward book with a primarily chronological theme. Its subject is big rockets, both military and civil, with particular emphasis on their adaptation and use for launching space vehicles.

The 80 pages of colour plates (by the John Wood Studio) cover the development of space launchers over the past 35 years, from Peenemünde and the V2 to the proposed space shuttle. They include cut-away drawings and photographs of most of the major American, West European, Russian and Japanese ballistic missiles and rockets – not forgetting our own Blue Streak and Black Arrow. The story outlined by these pictures is amplified by 150 pages of text, plus an alphabetical index. Political as well as technical factors are dealt with.

It is hardly necessary to say that the author – the current President of the BIS – needs no introduction to readers of this magazine. He brings to his subject a wealth of experience, gained through close association with space programmes on both sides of the Atlantic. In his Preface he makes a poignant reference to the fact that, within a short period, he was able to visit both a missile site in America and its presumed target in the Soviet Union. Readers will find many such personal touches in this authoritative and absorbing little book.

JOHN R. MILLBURN

Pioneer Odyssey: Encounter with a Giant
By R. O. Fimmel, W. Swindell & E. Burgess. National Aeronautics & Space Administration (SP-349), 1974, pp. 171, $5.50.

We are all familiar with the spectacular success of Pioneer 10 and the spacecraft's achievements: the first space probe to fly beyond the orbit of Mars and through the potential danger of the asteroid belt, the first to provide close view images of Jupiter and some of its satellites, the first to measure the space environment beyond Mars, around Jupiter and beyond, and, of course, Pioneer 10 will be the first man-made artefact to leave the solar system and enter interstellar space! This NASA publication is typically well produced and describes the Pioneer 10 mission from its inception through to the Jupiter encounter. The text is generally non-technical. The first chapter builds up a general picture of Jupiter as generally regarded before the mission, and gives brief mention to the basic mission objectives – subsequently dealt with in detail in the following chapters beginning with an overview of the project. Each experiment and associated equipment is described and illustrated. Not unnaturally, much space is given to the images obtained of Jupiter.

The pictures are well reproduced in colour as well as in black and white, with a fascinating account of the mechanism by which the images were constructed, using the Imaging Photopolarimeter (IPP). Since the IPP could only construct red and blue images, a synthetic green component was later added to reconstruct the colour pictures. It is fortunate that Jupiter itself has, in fact, no significant colouration.

Also dealt with is the interpretation of the on-board experiments during both the Earth-Jupiter transit phase of the mission and the Jupiter encounter. Intriguing are the results of measurements of Jupiter's major satellites, including spin-scan images of Ganymede and Europa. Physical measurements show Io (comparable in size to Mercury) to possess an atmosphere extending to some 115 km above its surface. Io was also discovered to possess an ionosphere, and this is, of course, within the magnetic field of the parent body, Jupiter.

New light has been thrown on Jupiter's most renowned feature – the Great Red Spot; close-up pictures also revealed a similar, but much smaller spot at the same latitude in the Northern Hemisphere. It would seem now fairly well established that such spots are meteorological effects (hurricane-type features) in the atmosphere.

All in all, an interesting and eminently readable review of the Pioneer 10 mission.

S. G. SYKES

"It is I, Sea Gull": Valentina Tereshkova, First Woman in Space
By Mitchell R. Sharpe, Thomas Y. Crowell Co., New York, 1975, pp. 214, $5.95.

The first chapter describes the hard times of Valentina's early life during the War-years in Maslennikovo and, later on, at school in Yaroslavl. There follows an account of working as a "stripper" – in a tyre factory, and then as a ribbon winder in a textile factory, leading on to a description of taking up parachuting and ending with her leaving for Moscow to be interviewed for a place in the cosmonaut corps.

Chapter 3 describes the Vostok spacecraft as a "spaceship for a Sea Gull" and is a brief history of the Soviet space programme from Tsiolkovsky up to Vostok. The black and white photographs, which are the best feature of the book, are curiously missing from this chapter. Good photographs of the Vostok spacecraft and its booster rocket have been available since 1967 and they should have been included.

The next chapter describes training and life in Star Town and the scene then moves to Tyuratam for the pre-launch activities. The subsequent account of the flight of Vostok 6 adds little, if anything, to what was already known. Later on in the book, describing a speech made by Valentina to the World Women's Congress, only five days after her landing, the author, in what I take to be a spirit of mild condemnation, refers to "material right out of *Pravda*" – to my mind this could very well sum up much of the author's own work!

Chapter 7 deals with the post-flight goodwill tours, the wedding of Valentina to fellow cosmonaut Andrian Nikolayev and the birth of their first child, Yelena. (Incidently there is no mention in the book of Alyonka, their other daughter.) On page 161 there is a very good photograph of Valentina following the presentation of our Society's Gold Medal during her visit to London in February 1964. The remainder of the book covers the Soviet manned spaceflight programme up to mid-1972 bringing in the deaths of S. P. Korolev, Yuri Gagarin, Vladimir Komarov and the crew of Soyuz 11. The reported failure of the giant booster is also mentioned. A short bibliography, a list of references and an index complete the book.

GEOFFREY PERRY